The AMSAT® Journal

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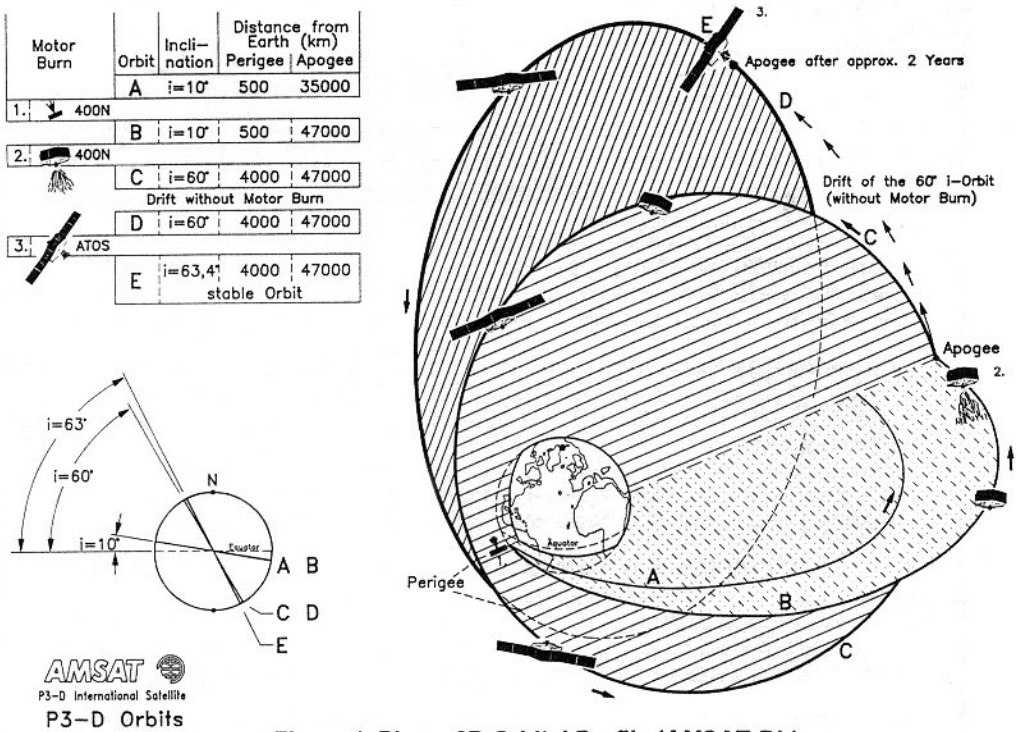

Figure 1. Phase 3D Orbital Profile (AMSAT-DL)

Phase 3D Orbit Estimation and Characteristics

by Ken Ernandes, N2WWD *(n2wwd@amsat.org)*

Phase 3D's orbit is a topic of considerable interest in the Amateur Satellite community. Much of this interest lies in pre-launch Keplerian elements, their evolution as the spacecraft progresses to its final orbit, and the expected communications opportunities from launch until Phase 3D achieves its final orbit. This article will attempt to address these topics.

Since a few of the terms used in this article may be unfamiliar to some, key words and concepts are defined in an addendum. I encourage you to refer to this addendum if an unfamiliar term is encountered.

[continued on page 4]

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Apogee View

By Bill Tynan W3XO

It has been a few months since I reported on the status of Phase 3D, so I feel it is time that our members be brought up to date.

First the bad news:

As has been mentioned in news releases following our Annual Meeting last October, the launch situation may not be what we had understood previously. From the beginning, Phase 3D was to have been launched on the second flight test of the new Ariane 5 vehicle (Ariane 502) being developed by the European Space Agency (ESA). However, an accord has been reached, involving a large amount of money, between ESA, Arianespace and Intelsat for launch of a large new Intelsat spacecraft (Intelsat 709) on Ariane 502. The mass of the spacecraft, along with the re-entry experiment which is also to ride, on 502, are such as to preclude accommodating Phase 3D. So, unless some unforeseen incident occurs, Intelsat 709 will ride on that mission and we won't.

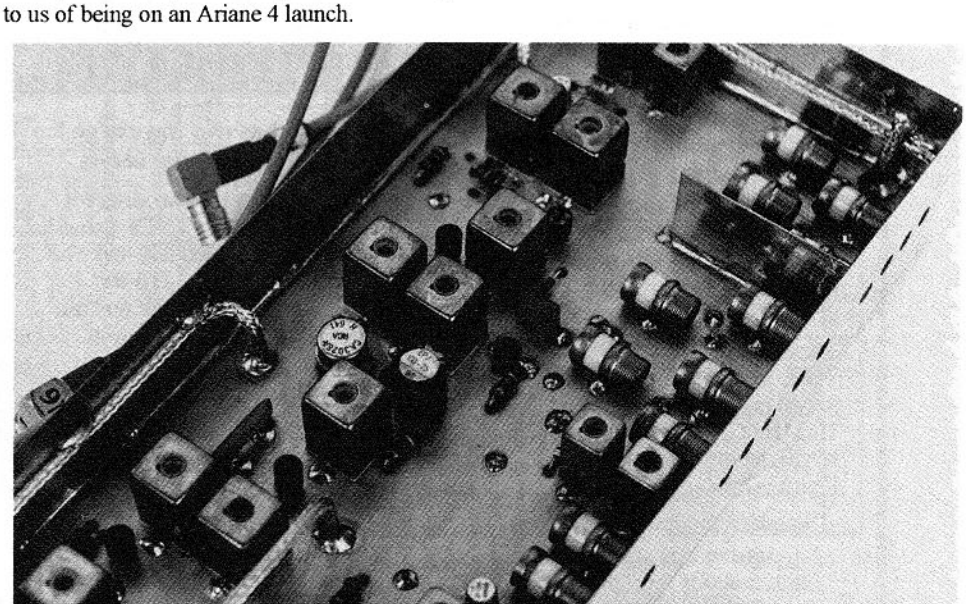
Now for the good news:

The Phase 3D Project Leader Karl Meinzer DJ4ZC has been assured by ESA that our spacecraft will be launched on an Ariane mission by mid-1997 at the latest. The launch is to take place on an Ariane 4 vehicle if not on 502. Since Ariane 4 is an operational vehicle with a fine history of success, there is a significant advantage to us of being on an Ariane 4 launch. From information received so far, it appears that the most likely time frame for the Phase 3D launch is sometime between December of this year and mid 1997.

Meanwhile, the completion of the satellite is proceeding. The wiring harness is all but complete. Schedules for delivery of the major electronic modules were agreed-to at a series of meetings recently held in Germany between DJ4ZC, DJ5KQ, DB2OS, WD4FAB and me. These schedules are compatible with completion and test of the satellite by early next fall, in ample time for a launch around the end of this year, and amateur operation beginning approximately three months later. Of course, if we don't get a launch until mid-1997, we will not be able to start using Phase 3D until sometime that fall.

So, there you have it. The news is not as good as all of us would have liked. Naturally, we wanted to have Phase 3D up and working before the demise of AO-13. It now is all be certain that this is not to be. Such is the way of the space business. Your might recall that NASA wanted to have the Shuttle flying in time to mount a mission to Skylab in order to attach rockets to it and thus save it from re-entry. This did not happen and the world lost its first space station.

You can be assured that all involved in the Phase 3D Project are making every effort to have our spacecraft ready for launch when ESA says it time to go.■



Close up detail of a second flight model 23cm receiver "front end" built by Dr. Mirek Kasal, OK2AQK for the Phase 3D satellite. (AMSAT-DL)

[PHASE 3D, Continued from pg. 1]

Orbit Modeling

The orbital modeling that follows is the result of my analysis, using available information. Since accurate pre-launch orbital parameters were not available for Phase 3D, I performed a first-order estimation. While this orbital estimation should be reasonably accurate, I will update these data once more definitive information becomes available.

The primary source of information for the orbital modeling was the AMSAT-DL Phase 3D orbit profile as shown in Figure 1. Phase 3D is manifested for the second Ariane 5 launch (AR502); the primary satellite will be inserted into a geostationary orbit. Therefore, the AMSAT-DL orbit profile was modified to conform to the Ariane 5 standard Geostationary Transfer Orbit (GTO) parameters. The only significant difference between the two is that the inclination of the Ariane GTO is 7° rather than the 10° listed in the AMSAT-DL orbit profile. Should Phase 3D be launched on an Ariane 4 instead of the Ariane 5, the orbit profile will need some modifications.

The Ariane booster will lift off from the ESA Kourou facility in French Guiana. Injection into the Ariane GTO occurs over the south central African continent, shortly after launch. Since the precise time from launch to injection was not provided by ESA, the modeled orbits are referenced to the GTO injection time.

Using the GTO injection parameters, a time-independent Earth-Fixed Greenwich (EFG) state vector was estimated. This vector was formatted for direct read by the Vector to Two-Line Elements (VEC2TLE) software and is as follows:

```
Vector format = 10107
Satellite Name:  AMSAT P3D
Catalog Number:  99934
Epoch MET:  0.00000000000
            0/00:00:00.000 MET
EFG E: 6690.568479 km
  F: 4512.845422 km
  G:  -706.058342 km
  Edot: -1.964268730 km/s
  Fdot: 8.228586607 km/s
  Gdot: -0.993119450 km/s
ndot/2 (drag): 0.00000001522 rev/day^2
nddt/6:  0.00000E+00 rev/day^3
Bstar:  2.46671E-05 1/Earth Radii
Elset #: 1
Rev @ Epoch:  1.51138979680
```

Two substantial orbital changes will occur following GTO insertion. These orbital changes will be made by Phase 3D's primary propulsion system: the 400N (95 lb.) thrust hypergolic motor.

The burn times listed in this article represent the earliest orbital event (apogee, perigee) in which the orbital change could physically be performed. Since there are other constraints on the spacecraft, the actual Phase 3D burn sequence will require several days. Some of the constraints (such as Solar angle) are dynamic depending on the situation resulting from the actual launch date and time. Therefore it is difficult or impossible to predict the actual apogee or perigee in which the burns will occur. The modeling used in this article should thus only be used for visualization purposes, with the actual burn times to be revised once the launch date and time are known.

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  - Satellite model allows simultaneous 9.6 uplink and 38.4 downlink for imagery satellites.

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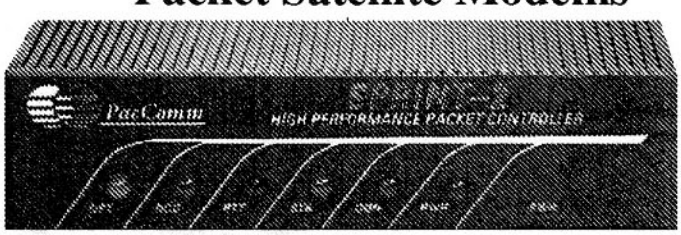

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Using the AMSAT-DL orbit profile, the first orbital change (Burn #1) occurs at perigee, presumably modeled here one revolution after GTO injection. This burn increases the apogee altitude from the Ariane GTO value of approximately 35,000 km, to the desired Phase 3D value of 47,000 km. The estimated Burn #1 parameters are as follows:

Burn #1
MET: 000/10:30:22.345
Intrack: 153.7 m/sec
Crosstrack: 0.0 m/sec
Radial: 0.0 m/sec

For simplicity, the orbit adjust burns are modeled as instantaneously impulsive (i.e., burn duration = 0 seconds). This presumption is approximately correct, and it eliminates the need to model vehicle mass and propellant mass flow rates.

Again using the AMSAT-DL orbit profile, the second orbital change (Burn #2) occurs at the ascending node near apogee, presumably modeled here one half revolution following Burn #1. This burn raises the perigee altitude from the Ariane GTO value of 500 km, to the desired Phase 3D value of 4,000 km. This burn simultaneously increases the orbital inclination from the GTO value of 7° to the *desired* Phase 3D value of 60°. The Burn #2 parameters are as follows:

Burn #2
MET: 000/18:07:32.258
Intrack: -374.2 m/sec
Crosstrack: 1239.7 m/sec
Radial: 114.6 m/sec

Estimated Keplerian Elements

The Keplerian elements following Burn #2 are of primary interest since this is the orbit in which Phase 3D will operate for approximately two years as it drifts to its final station. Unfortunately, the Keplerian elements following Burn #2 are not obvious from the above state vector and burn information. However, they can be generated by computing the GTO from the State Vector and applying the effects of Burn #1 and Burn #2 at the appropriate times. These computations may be readily accomplished using VEC2TLE.

The Keplerian elements for the initial orbit (perigee altitude = 500 km, apogee altitude = 35,000 km) were estimated by VEC2TLE from the state vector. (This was accomplished by "Read Vector File" under the "Compute TLE" menu.) Using a 15-SEP-96 / 12:00 UTC injection time (as an example), the following Keplerian elements were determined:

Satellite: AMSAT P3D
Catalog number: 99934
Epoch time: 96259.50000000
Element set: 1

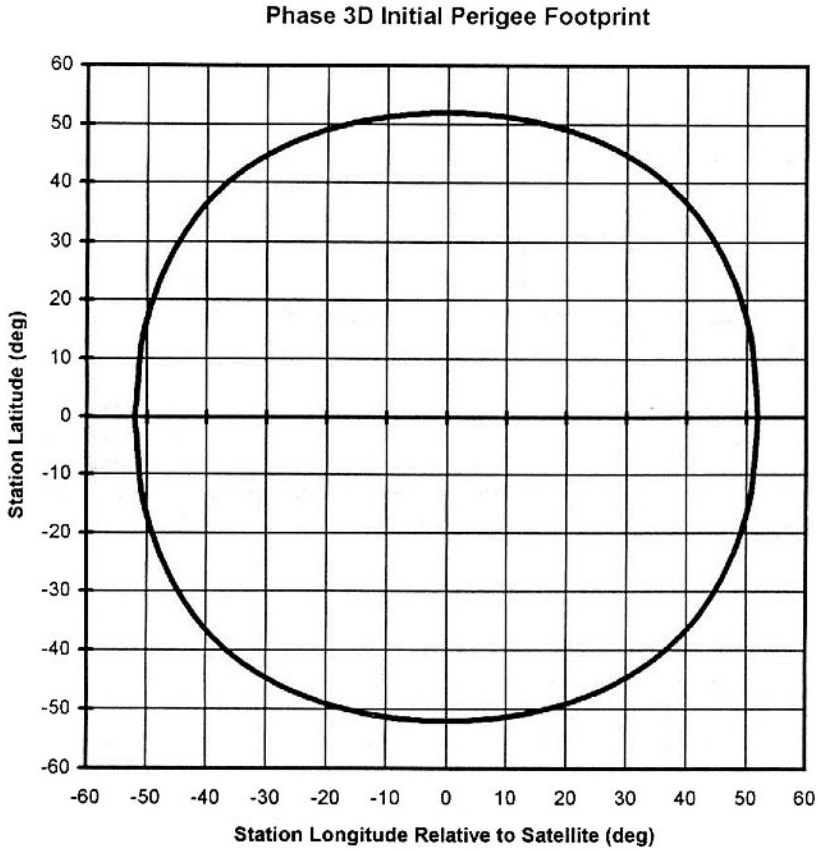

Figure 2. Phase 3D Initial Perigee Footprint

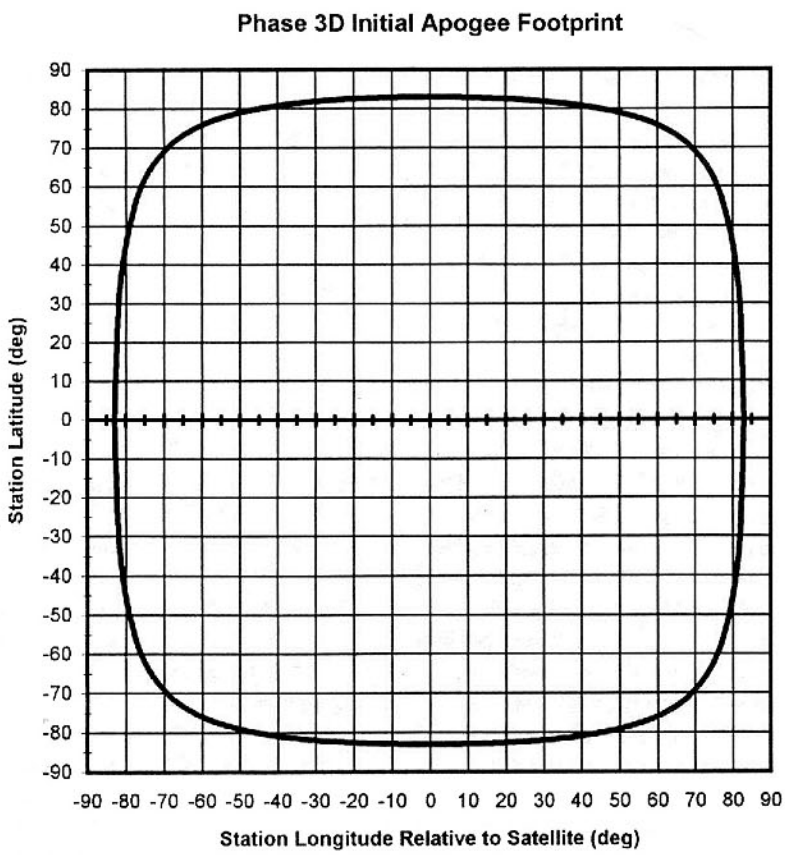

Figure 3. Phase 3D Initial Apogee Footprint

Inclination: 7.0000 deg
RA of node: 343.2717 deg
Eccentricity: 0.7160512
Arg of perigee: 178.0284 deg
Mean anomaly: 6.0876 deg
Mean motion: 2.24345803 rev/day
Decay rate: 1.52000e-08 rev/day^2
Epoch rev: 1

In the next step, VEC2TLE was used to estimate the post-Burn #1 Keplerian elements. (This was accomplished by "Impulsive Delta-V" under the "Compute TLE" menu.) The resulting Keplerian elements (perigee altitude = 500 km, apogee altitude = 47,000 km) are:

Satellite: AMSAT P3D
Catalog number: 99934
Epoch time: 94259.93775862
Element set: 2
Inclination: 7.0001 deg
RA of node: 343.1106 deg
Eccentricity: 0.7698019
Arg of perigee: 178.1741 deg
Mean anomaly: 359.7573 deg
Mean motion: 1.63753437 rev/day
Decay rate: 2.00000e-08 rev/day^2
Epoch rev: 2

Finally, VEC2TLE was used to estimate the post-Burn #2 Keplerian elements (again using "Impulsive Delta-V" under the "Compute TLE" menu). The resulting Keplerian elements (perigee altitude = 4,000 km, apogee altitude = 47,000 km) are:

Satellite: AMSAT P3D
Catalog number: 99934
Epoch time: 96260.25523447
Element set: 3
Inclination: 60.0203 deg
RA of node: 342.7876 deg
Eccentricity: 0.6752895
Arg of perigee: 180.1221 deg
Mean anomaly: 179.5089 deg
Mean motion: 1.51063968 rev/day
Decay rate: 2.00000e-08 rev/day^2
Epoch rev: 2

Using the state vector and burn data provided, you can use VEC2TLE to reproduce the above results. This process is also useful for estimating the Keplerian elements corresponding to the actual Phase 3D launch date and GTO injection time. (Note: when applying Burn #1 and Burn #2, be sure to specify Vector Units as "km, km/s" and Vector Time Reference as "MET" under the VEC2TLE "Settings" menu.)

Apogee-Perigee Drift

The post Burn #2 orbit was designed with the intent that its apsidal (apogee-perigee) line would drift, with apogee moving into the northern hemisphere. This apsidal drift is a natural orbital perturbation resulting from the Earth's non-spherical mass distribution (i.e., the equatorial bulge). Basically, the Phase 3D orbit design takes advantage of the Earth's natural imperfection to have apogee drift into the northern hemisphere.

The apsidal drift rate varies as a function of orbital inclination as well as apogee and perigee altitudes. The apsidal drift rate for the post Burn #2 orbit will depend primarily on how closely the planned 60° inclination is achieved. If it is nominal, the drift will *initially* be about one degree per 68 days. This drift rate will *change* somewhat as gravitational attraction from the Sun and Moon cause variations to the apogee and perigee altitudes (the same forces causing the demise of AO-13's orbit).

As Phase 3D approaches its final apogee location, the spacecraft's 0.1N Ammonia Arc Jet thruster will be used to neutralize the apsidal drift. This will be accomplished by slowly changing the orbital inclination to 63.43° over a period of time. (Note that 63.43° is the critical inclination for which there is zero apogee-perigee drift.) Since inclination change maneuvers are very expensive in terms of propellant consumption, Burn #2's 60° inclination was carefully selected to be close to the stable 63.43° inclination. This choice was made to conserve the Arc Jet thruster's propellant for later orbital maintenance, yet still have enough apsidal drift so apogee will move into the northern hemisphere.

The slowly changing drift rate results in an approximately two year time period for apogee to reach its final location. The net apogee drift will depend on the apsidal drift rate as a function of time, which primarily depends on how closely the planned Burn #2 orbit is achieved. The total apogee drift will be the difference between final value for the argument of perigee and its initial value of 180•. The apogee latitude of the final orbit can be calculated from the argument of perigee (ω) and the inclination (i= 63.43°) as follows:

$$Lat_{apogee} = \arcsin[-\sin(\omega)\sin(i)]$$

Satellite Coverage

Since Phase 3D will be in a highly elliptical orbit, the ground footprint will vary with altitude; the higher the altitude, the larger the footprint. The Phase 3D footprint will vary from about 19% coverage at perigee (about one fifth the Earth's surface) to about 44% at apogee (nearly one half the Earth's surface). This may be compared with Radio Sputnik 15 (RS-15), whose apogee footprint has less than 13% coverage (a little more than one eighth of the Earth's surface).

When the spacecraft's apogee-perigee line is on the equator (near-term following Burn #2), the footprint may be characterized by coverage in latitude and longitude. Figure 2 provides a plot of the initial perigee footprint; Figure 3 provides a plot of the initial apogee footprint. Note that the longitudes for stations covered by both of these charts is *relative* to that of the satellite (i.e., the satellite is located at the center of both plots).

In reviewing Figures 2 and 3, you may question why the apogee footprint is so much more "square" than the perigee footprint. Both of these footprints are projected on two-dimensional plots in the figures, but in reality they are on the Earth's spherical surface. Since the perigee footprint is only about a fifth of the Earth's surface, it is only slightly distorted when projected on its flat plot. However, since the apogee footprint covers nearly half of the sphere, its flat plot has significant distortion.

Ground Track Repetition

Phase 3D's (47,000 x 4,000 km) orbit will have an 18 hour period, resulting in three revolutions of the Earth every two days. The apogees for each of the three revolutions will be separated evenly around the Earth, with a 48 hour repeating pattern. This will provide a fairly repeatable pass schedule for tracking this satellite, allowing for simpler antenna pointing calculations.

Updates To Phase 3D Orbital Data

I will make updates to the injection State Vector or nominal burn data available as soon as possible via the AMSAT Internet mailing list (*amsat-bb@amsat.org*) and for possible release through AMSAT Bulletins. These Phase 3D orbital data will be also posted under the State Vector tutorial on the AMSAT World-Wide Web (WWW) Internet page. The Uniform Resource Locator (URL) for the State Vector tutorial is:

http://www.amsat.org/amsat/sarex/vectors.html

This same Phase 3D estimated orbital data will also be available by anonymous FTP at the AMSAT site:

ftp.amsat.org /amsat/keps

Additionally, the VEC2TLE software may be purchased directly from AMSAT-NA or may be downloaded from the Space Shuttle Orbital Data on the AMSAT WWW page or the AMSAT FTP site. The URL for the Space Shuttle Orbital Data is:

http://www.amsat.org/amsat/sarex/orbit.html

Conclusion

The information provided represents my estimate as to what orbits and geometry may be expected, given a nominal Phase 3D launch. Since much depends on the launch date, initial orbit achieved, and *actual* orbits achieved following Burns #1 and #2, some important questions will remain un-answered until launch occurs. However, the footprints (Figures 2 and 3) indicate an orbit with some very exciting coverage and contact opportunities. Coupled with the capabilities of this spacecraft, Phase 3D promises a new era in Amateur Radio communications.

Editor's Note: Ken's article was submitted prior to learning of the recent change in Phase 3D's possible launch on an Ariane 4. As a result, Ken's methodology for rapidly estimating Phase 3D's Keplerian elements will be put to test. He will be making an alternate set of nominal vectors based on an Ariane 4 launch. Stay tuned to future journal articles, ANS Bulletins, and Internet messages on this topic.)

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Addendum: Key Words and Concepts

This section was included to provide brief definitions of key words and concepts. This information should clarify subjects of which you may not be familiar. The subjects are organized alphabetically.

Apogee: The highest altitude in a satellite's orbit.

Apsidal Line: The apogee-perigee line of an orbit.

Argument of Perigee: The angle measured from an orbit's ascending node to its perigee, in the direction of satellite motion.

Ariane: The family of space launch booster rockets used by the European Space Agency (ESA).

Ascending Node: An orbit's south-to-north equatorial crossing point.

First-Order Estimation: A *close enough* analysis that is done to get *ballpark* numbers when all information is not precisely defined. We do a first-order estimation during preliminary stages of design and/or when we are not as concerned about being exact as we are about being close. There is no point in running a computationally intensive, high-fidelity simulation if we are uncertain as to the value of a significant parameter. To do so would be much like measuring things with a micrometer, marking them with a chalk, and then cutting them with a chain saw.

Footprint: The area on the Earth's surface with direct line-of-sight to the satellite.

Geostationary Orbit: A high-altitude (35,000 km), equatorial orbit that is synchronized with the Earth's rotation. Since the satellite orbits at the same rate in which the Earth rotates, the satellite appears stationary over the Earth. This feature makes this orbit type very popular for communications satellites. This is also known as a Geostationary Earth Orbit (GEO) or a Clarke orbit (after author Arthur C. Clarke who first realized this orbit's usefulness).

Geostationary Transfer Orbit (GTO): An intermediate elliptical orbit that serves as the pathway from a Low Earth Orbit (LEO) to a GEO. The GTO may be thought of as the *exit ramp* from LEO and then as the *entrance ramp* to GEO. Phase 3D will be injected directly into a GTO along with the primary satellite by the Ariane 5 booster.

Hypergolic: Hypergolic propellants ignite spontaneously upon contact of the fuel and oxidizer. This simplifies rocket thruster design since the two components just need to be injected into the combustion chamber to commence burning.

Impulsive Burn: A short duration thruster firing in which a velocity change is nearly instantaneous.

Inclination: The *tilt* angle of a satellite's orbit (with respect to the equator). This also represents the highest and lowest latitudes over which the satellite will fly.

Inclination Change: A maneuver that changes the inclination of an orbit. Inclination changes consume a considerable amount of propellant since they literally re-direct the path of an extremely high velocity object by the number of degrees of inclination change. For example, to re-direct the Space Shuttle (~17,500 mph) by just three degrees requires a velocity change of about 916 mph.

Injection: Orbital insertion which occurs when a satellite is deployed from a launch booster following thrust termination.

Perigee: The lowest altitude in a satellite's orbit.

Period: The time required for a particular satellite to make one complete orbit of the Earth.

Perturbation: A deviation from *perfect* orbital motion (as predicted by Kepler's laws). These deviations result from external or complex forces, rather than the satellite-Earth gravitational attraction on which Kepler's laws are based.

State Vector: The instantaneous position and velocity of a satellite. Position is expressed as the three components (such as X, Y, and Z) of the satellite's distance from the center of the Earth. Velocity is expressed as the three components of the satellite's speed along the same coordinate axes (X, Y, and Z) as were used for position.■

Mars Global Surveyor Part 2 : Orbital Maneuvers and Radio Science Experiments

John L. Callas, Jet Propulsion Laboratory
Michael R. Owen, W9IP, St. Lawrence University

The orbit insertion phase of the Mars Global Surveyor mission is the period of transition from the interplanetary trajectory to the mapping orbit around Mars (Figure 1). This phase extends from the beginning of the Mars Orbit Insertion (MOI) sequence, until the spacecraft is established in the mapping orbit and declared ready to begin science data collection. Due to the length of the orbit insertion mission phase and the number of critical events contained within it, three sub-phases have been defined:

1) *Mars Capture* sub-phase, begins with MOI and extends nine days until the start of aerobraking.

2) *Aerobraking* sub-phase in which the orbit is reduced from the initial capture orbit down to a "near" 2:00 p.m. Sun-synchronous polar mapping orbit.

3) *Transfer to Mapping* sub-phase in which the final mapping orbit is achieved and the spacecraft and payload are configured for mapping operations.

Mars Capture Sub-Phase

Mars Orbit Insertion (MOI) will slow the spacecraft and allow Mars to capture it into an elliptical orbit. Before the orbit insertion burn, the spacecraft's velocity relative to Mars will be approximately 5 km/s. Near the point of closest approach on spacecraft's in-bound trajectory, the main engine (596 N) will fire for approximately 20 to 25 minutes to provide a slow down of roughly 980 m/s. This burn will take the spacecraft off of the hyperbolic approach trajectory and onto an elliptical capture orbit with a period of 48 hours and periapsis altitude of 314 kilometers.

Aerobraking Sub-Phase

The basic problem in designing the orbit insertion strategy is that MGS does not have enough propulsive capability to achieve the low altitude Sun-synchronous mapping orbit, due to the mass of the spacecraft (about 660 kg) and the capability of the Delta 2 launch vehicle. MGS will instead aerobrake from the initial 56,662 km apoapsis altitude of the Mars capture orbit down to the required 450 km altitude.

Aerobraking is the utilization of atmospheric drag on the spacecraft to reduce the energy of the orbit. Friction caused by the passage of the spacecraft through the atmosphere provides a velocity change at periapsis, which results in the lowering of the apoapsis altitude. This is similar to the final stages of the AO-13 orbit decay.

The rate at which the apoapsis altitude decreases is determined by how much drag is generated and the resulting velocity change at periapsis. Going deeper into the atmosphere will provide greater drag and reduce the orbit faster, but will consequently generate higher spacecraft temperatures and dynamic pressures. Aerobraking is comprised of three distinct phases designated as "walk-in," "main-phase," and "walk-out". These three sub-phases, described below, require approximately 130 Earth days to complete.

Aerobraking Walk-In

The walk-in portion of the aerobraking sub-phase is 20 days in duration and represents the initial period of aerobraking where the periapsis altitude is lowered in four steps via apoapsis propulsive maneuvers ("burns") to the desired main phase altitude. The need for a gradual walk-in is due to the large uncertainty in the atmospheric density model of Mars. Additionally, the start of the aerobraking phase coincides with the start of the Martian dust storm season. The effect of the dust storms on the atmosphere is to increase atmospheric heating which propagates to the top of the atmosphere and causes the atmospheric density to increase. How rapidly the atmospheric density changes at the main phase periapsis altitude as a result of these dust storms is not well known. Thus the

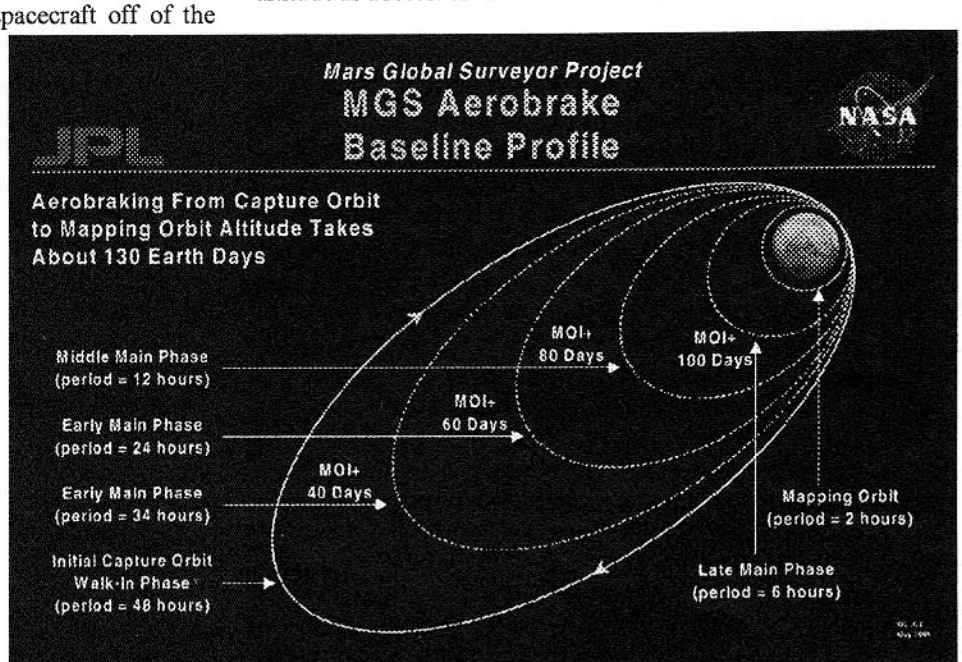


Figure 1. Aerobraking is a technique for circularizing an orbit by "dipping" into the planet's atmosphere at periapsis (perigee). This procedure will gradually reduce the apoapsis (apogee) altitude and change the MGS's original elliptical orbit into a nearly-circular orbit. The aerobraking phase will require about 4 months to complete.

time interval between walk-in maneuvers allows for multiple orbits in which Earth-bound navigation can determine atmospheric density and adjust burns on an orbit-to-orbit basis.

Aerobraking Main Maneuver

The majority of the orbital energy is removed during the 82-day aerobraking main maneuver. The MGS uses small propulsive maneuvers (ABMs), executed at apoapsis, to maintain periapsis within a well-defined periapsis altitude corridor which is low enough to produce enough drag to reduce the orbit within the time constraints imposed by the 2:00 p.m. orbit, yet high enough to avoid spacecraft heating limits and maximum allowable dynamic pressure to maintain control authority over aerodynamic torques. Due to the oblateness of the Mars, the altitude of periapsis tends to rise during the main phase, so that the ABMs will be in the "down" direction to lower the periapsis altitude.

Walk-Out Segment

The walk-out segment of the aerobraking sub-phase requires approximately 16 days and represents the final stages of aerobraking when the apoapsis altitude rapidly approaches the desired 450 km. The periapsis altitude is raised with daily ABMs, to decrease the dynamic pressure in order to maintain a 3 day orbit decay period. The 3 day orbit decay period is critical for recovery from any anomaly which would prevent the execution of the next periapsis raise maneuver. When the desired apoapsis altitude is reached, the ABX maneuver is performed to raise periapsis to 350.8 km, ending the aerobraking phase.

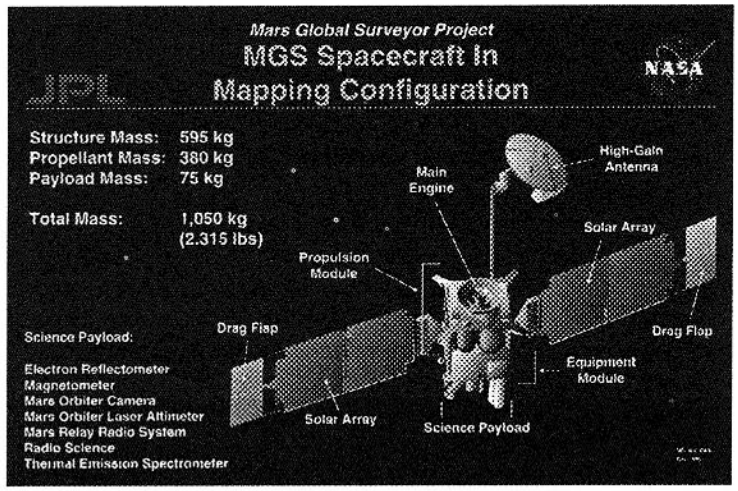
Transfer to Mapping Sub-Phase

The mapping orbit for MGS is a low-altitude, near-circular, near-polar orbit which is Sun-synchronous with the dayside equatorial crossing at 2:00 p.m. mean solar time, all of which have nearly been achieved upon completion of the aerobraking phase. In order to meet altitude variation requirements in mapping for the instruments and the horizon sensor (MHSA), the mapping orbit must also be a frozen orbit with a stationary periapsis location around the South Pole.

Upon completion of ABX, the periapsis latitude may be anywhere between 6° S and 42° N depending on how much time was required for the aerobraking maneuver. Propulsively moving periapsis down to the South Pole is beyond the capability of the propulsion system. The effect of the gravity field, however, is to move periapsis towards the South Pole at approximately 3.25°/day. Thus periapsis reaches the South Pole in 26-37 days. Once periapsis is in position, the Transfer to Mapping Orbit (TMO) maneuver is executed with the main engine to acquire the mapping orbit.

Radio Science

Most Radio Amateurs tend to think of radio as principally a tool for communications. However, the behavior of radio signals can also provide valuable information in addition to any "message" attached to the signal.



View of the Mars Global Surveyor as it will be deployed during it 2-year mapping of Mars. Solar panels and high-gain antenna may be rotated to maintain favorable orientation while the orbiter camera remains aimed at Mars' surface.

The Mars Global Surveyor will use radio signals to learn about the atmosphere and rocky interior of Mars in a way that satellite enthusiasts may appreciate. Using an ultra-stable oscillator with outputs at X-Band (7.164 and 8.417 GHz), the MGS will transmit telemetry back to Earth. In addition to the actual data contained in the telemetry, the characteristics of the X-band signal itself will provide important information.

The Doppler shift of the X-Band signals will reveal the spacecraft's velocity, similar to Doppler shift of Earthly satellites. More information may be gleaned by observing how the Doppler shift changes with time. As the spacecraft passes over denser areas of Mars, the acceleration due to gravity will increase so the velocity of the satellite will increase ever-so-slightly. Monitoring the telemetry signal will therefore reveal the distribution of mass, therefore the density of rocks, and indirectly the kinds of rocks that make up Mars.

Radio science has additional important uses in the Mars Global Surveyor project. For example, for the few moments just as the spacecraft passes behind Mars, its telemetry signal will pass through Mars' tenuous atmosphere. Repeated measurements of the fading characteristics of the signal will tell scientists about the composition and vertical structure of Mars' atmosphere.

Glossary

Periapsis: Equivalent to perigee, the point in an orbit closest to the surface of the planet
Apoapsis: Equivalent to apogee, the point in an orbit farthest from the planet.■

UNAMSAT WEB Page

David Liberman, XE1TU informs us that The National Autonomous University of Mexico (UNAM) now has the following WWW pages:

- For UNAM: *http://www.unam.mx*
- For UNAMSAT: *http://serpente.dgsca.unam.mx/unamat/unameg.html*

Thermal Analytical Modeling of Phase 3D

Dick Jansson, WD4FAB

Summary

The international Amateur Radio community commenced its participation in the Phase 3D Project (P3D) at a meeting in Marburg-Michelbach, FRG, in May 1990. At that meeting, this writer was requested to head-up the Mechanical Design efforts for the Project, as well as conducting the needed Thermal Design activities. This coupling of these two efforts in the Mechanical Engineering area has proved to be very useful. These design technologies have been conducted hand-in-hand, rather than one being done without the knowledge of the other. (Another term for the separated process is *designing in a vacuum*.)

A physical-mechanical embodiment of a P3D spacecraft has existed in three considerably different configurations, each taken to a reasonable level of design detail. The 1990 meeting directed the consideration of a roughly cubical satellite with a volume of approximately two cubic meters, a cubical volume of 1.2m (48in.) on a side. At the subsequent P3D meeting in May 1991, the cubical P3D design was discarded, for some very good reasons. In its place, the triangular *Falcon* spacecraft configuration evolved. In November 1992, that spacecraft design had to also be discarded because of major launcher interface changes by ESA. Both of these spacecraft designs had received thermal design consideration, with the Falcon design receiving an extensive amount of effort. Following November 1992, about six spacecraft designs were evaluated with principal thermal design considerations being included for all. This activity distilled down to the current spacecraft design, the hexagonal prismatic configuration, of which many photographs and sketches have been published.

Starting in December 1993 and through the first months of 1994, a major thermal analytic model of the P3D spacecraft was constructed, and a substantial analytic effort was conducted. As a result of this effort, a viable thermal design exists for the three-axis stabilized spacecraft operation. Undone as of this writing is the taking of the P3D thermal model into the spin-mode operational phase, the spacecraft operational configuration at the time of its initial injection into orbit from the Ariane launcher. This omission is not of a great concern, however, as experience has taught us that these conditions are a benign extension of the oriented mode design. We found that the basic spacecraft thermal design has the latitude and ability to place the overall Phase 3D operating temperature where it is desired, through control of the amount and locations of thermal control tapes of several types. This design employs no difficult-to-construct multi-layer insulation blankets, as were used on AO-10 and AO-13. Furthermore, this analysis clearly reinforces prior analytic observations that the internally mounted heat pipe design is a very sound concept.

Model

The thermal analytical model of the Phase 3D spacecraft has been constructed to provide significant details of the temperatures of each module and the heat pipe areas. This model, while a bit restrained in size, still is large and consists of a network of some 450 nodes, 3,750 conductors and is a large ASCII file of about 338 kilobytes (and growing!), or about 60 pages of text at 96 lines per page. Dealing with such a large model involves a considerable amount of data bookkeeping. To date, the model does not contain P3D's communication antennas, they need to be added as the next step of model construction. This omission was done in 1994 as the detailed antenna information did not exist. Keeping the model external geometry simple allowed the basic thermal coating design concepts to be established without undue complications.

The thermal model is computed as a steady-state analysis, rather than a more complex transient analytic model, for each of eleven solar angles, ß = 0°, ß = ±10°, ß = ±20°, ß = ±40°, ß = ±60°, and ß = ±80°. The solar angle is represented by the Greek letter, ß, and is defined as that angle between the satellite-sun line and the satellite (nominal horizontal) XY plane, with the sun maintained in the satellite +XZ plane (that is, pointing at the solar panels) and the antennas pointed along the (spacecraft top) +Z axis toward the Earth. As the 16 hour orbital period is rather long, general steady-state temperatures will exist and transient orbital computations are not warranted for these modes of operation. The range of ß angle computation permits an evaluation for nearly all anticipated spacecraft attitudes and solar positions. Neither Earth shine (planetary emission) nor albedo (reflected sunlight) are considered for these computations, as the orbital altitudes for P3D make their effects totally negligible. The preliminary operation of this P3D thermal model required 11-12 hours of computational time using a 486 DX2-66 MHz and later analyses required only 3.7 hours on a Pentium 90 computer with the same model.

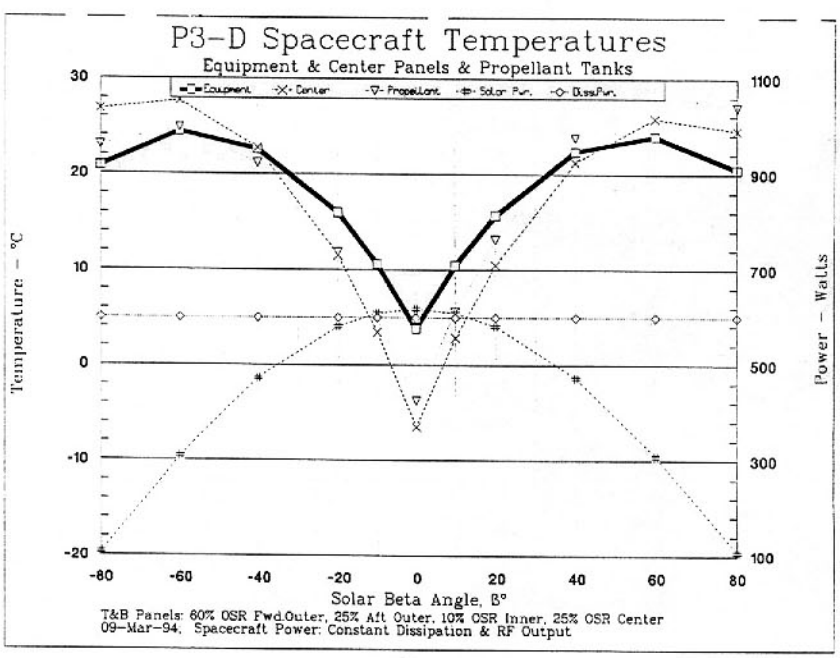


Figure 1.

Output

Spacecraft temperatures plotted as a function of ß angle produce an often seen *butterfly* pattern of temperatures with a pronounced minimum temperature at ß = 0°, as shown in Figure 1. Such a temperature plot is to be expected for purely geometric reasons. The geometric projected area of the spacecraft as it is illuminated by sunlight, changes rather dramatically as it tilts away from ß = 0° to positions with the top or

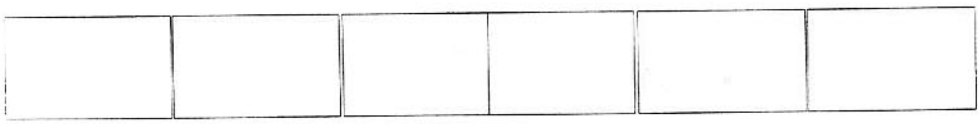


Figure 2a. P3D Spacecraft Solar Projected Area, β = 0°.

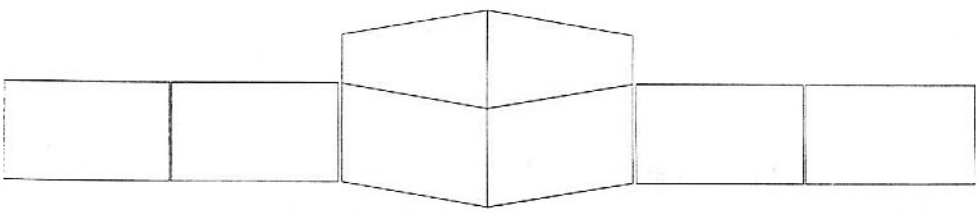


Figure 2b. P3D Spacecraft Solar Projected Area, β = 20°.

bottom being progressively exposed to sunlight. Figure 2a shows this point with one view of P3D at ß = 0° and Figure 2b at ß = 20°. The change in the area *seen* by the Sun amounts to an increase of 20% at the later ß angle. The designer must counter these realities of geometry with degrees of 'gamesmanship' in selecting and placing the thermal coatings on the top and bottom of the spacecraft so as to minimize the effects of the change in solar illumination.

The first thermal analytic computations were performed using a constant electrical power dissipation model, Figure 1. It was found that this effort started to lead to an improper set of thermal coatings. A more realistic power model, Figure 3, was then incorporated insuring the power margin to the batteries was always at least slightly positive over the range of ß = ±70°, controlled by turning on or off certain transmitters and equipment as a function of ß angle. The negative power margin at the extreme ß angle altitudes does not reflect spacecraft operating realities. This power model is also shown in Figure 3. All operating modes maintained at least two transmitters in operation. This is all as is expected of the planned operation of P3D, as will be determined by the team of P3D command stations. It needs to be pointed out that accurate and representative power modeling is an essential element of a good thermal analysis. Just making simple assumptions about the power dissipation of a module is quite incorrect, and the designer needs to thoroughly interrogate the Electronic Designers for detailed power data for all modules.

The average equipment panel temperature varies from ≈ +4°C to ≈ +12°C and down to ≈ -11°C, well within the intended spacecraft design range. It should be noted that modular temperatures are well dominated by the equipment panel temperatures, despite modules being exposed to some rather cold spacecraft side panels. Six high power modules are directly coupled to the heat pipe system through the use of especially designed heat sink modules. All of the other modules are coupled to the equipment panels and the heat pipe system through purely radiative heat transfer means. Modular proximity to the equipment panels permits the dominance of those panels over modular temperatures, despite the cold side panels nearby. These spacecraft side panels, four of them on sides 2-5 (those sides which formerly had deployable solar panels covering them in the launch configuration) are deliberately painted to make them cold and the major area for heat rejection to space for the entire spacecraft.

Future Efforts

While the analytic model created in 1994 used modules placed in the anticipated locations of 1994, those positions did not necessarily reflect the final positions for as they are in 1996, although there are not too many changes to be made. Not only are modular positions being adjusted for model reality, modular power dissipations and operating time characteristics will need to be tracked and will be accurately modeled in the planned pre-flight analyses. Most obviously, P3D antennas are being incorporated in the model to determine their effect upon the thermal control coatings of (especially) the spacecraft top surface. In this direction, the modeling effort has identified ≈ 25 *items* on the top of the spacecraft. It is a busy place.

Future analytic activities will be conducted with Phase 3D in launch configuration, where the solar panels are clamped to all six sides of the spaceframe and with the spacecraft spinning about its Z axis. As was done for the Phase 3A spacecraft of 1979, an analytic model operation must be performed to evaluate the effects of a solar eclipse (by the orbit path being in the Earth shadow). Under this condition, most of the structure will become quite cold. However, some critical modules will not become too cool, due to the deliberate isolation characteristics of the thermal design of their mounting. There is a lot of work ahead.

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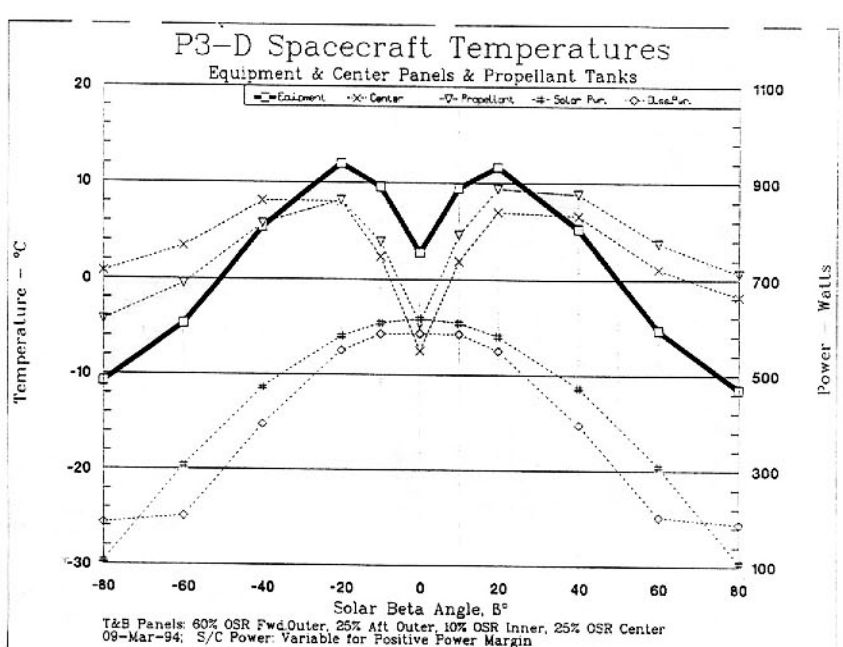

Figure 3.

Pointing Satellite Antennas

Walter Schulz, K3OQF/VQ9TD

Recently AMSAT President, Bill Tynan, W3XO, wrote an editorial about the progress of Amateur Radio satellites and their future (Apogee View, *The AMSAT Journal*, May/June 1995). He mentioned the pros and cons of a Phase IV satellite. Geostationary satellites are interesting to me as a radio amateur and as a radio operator onboard merchant ships. I use the maritime geostationary satellites to send and receive message traffic, and can attest to the communication efficiency these satellites offer. It is obvious that amateurs would welcome the benefits this class of satellites offer.

There is relatively little information in general radio amateur literature about pointing antennas at celestial objects. Only the ARRL's *The Satellite Experimenter's Handbook*[1] describes methods that can be utilized to point antennas towards satellites. Since I use geostationary satellites every day, I have developed techniques for antenna pointing based on navigational methods. While most amateurs would not turn to navigation concepts to solve this problem, I did because navigation books and references are readily available onboard ship. During one voyage I needed to know how to point the antenna at a geosynchronous satellite after making repairs to the antenna platform. That repair led to the method described here.

It occurred to me that a geosynchronous satellite could be treated as a celestial body. Once a geographical position on the Earth's surface and the point on the Earth's surface directly below the satellite (the sub-stellar point) are known, the solution to the navigational triangle can be found (See Figure 1 — Navigational Triangle). In order to provide the accuracy required by high resolution antennas, a correction (Parallax in Altitude correction) must also be made.

I can illustrate this method with an example. Suppose an amateur in the Boston area (42.4 degrees North Latitude and 70.05 degrees West Longitude) wants to point a satellite antenna at the Atlantic Ocean Region - East Satellite (0 degrees latitude and 18.5 West Longitude).

Elevation Angle to the Satellite (Height above the Horizon)

First I find the difference between Boston's longitude and the satellite sub-stellar longitude (Δ).

Let Δ = 70.05 deg - 18.5 deg = 51.55 deg

Δ = 51.55 deg

The amateur radio station's latitude is Φ = 42.4 degrees *North*. Next I'll find Y (Great Circle distance in degrees from Boston to the Sub-Stellar position on Earth's surface.

$Y = \arccos [(\cos\Phi)(\cos\Delta)] = \arccos [(\cos 42.4\text{deg})(\cos 51.55 \text{ deg})]$

$Y = \arccos[(0.7385)(0.6218)] = \arccos [0.4592] = 62.6631$ deg

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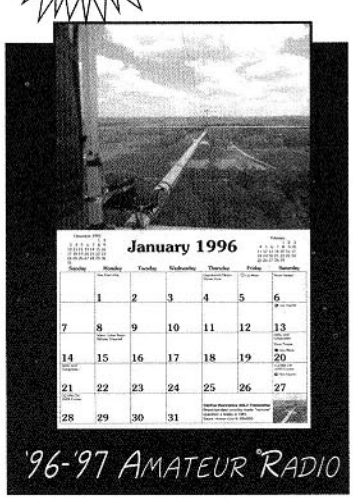

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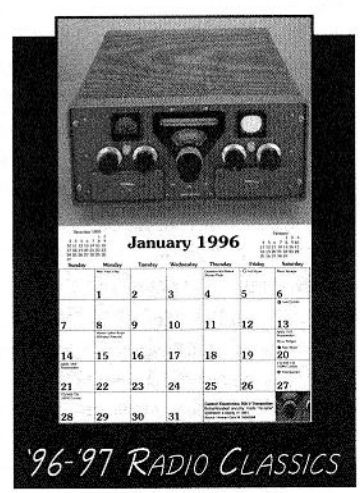

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Then I'll find the satellite's uncorrected height (elevation angle) above the Earth's horizon:

90 deg - Y = *Height (uncorrected)* = 90 - 62.6631 = 27.3379 deg

Finally, I must correct the Parallax error to obtain an accurate elevation angle to the satellite.

Geosynchronous satellites orbit the Earth at 35,786 Kilometers (km) from the Earth's surface. The Earth's radius is 6378 km (Re = Radius Earth). Therefore, the satellite orbital radius, taken from the Earth's center to orbital path is 42,164 km (Ro = Radius Orbit).[3] The satellite's orbit is close to Earth. Horizontal Parallax (HP) is equal to *radius of Earth divided by the distance of the body from the center of the Earth.* It then follows:

sin*HP* = *radius/dist* = 6,378 Km/42,164 km = 0.1513

and the correction factor for Horizontal Parallax:

HP = arcsin (0.153) = 8.7 deg *correction*

No matter what geographical position (GP) on the Earth's surface, the satellite antenna will always be pointing toward the satellite on the equator and downwards from the Earth's poles. Therefore, it's reasonable to assume Horizontal Parallax will be a minus correction factor taken from Height above the Horizon uncorrected.

PARALLAX - in - ALTITUDE = 8.7 COS(HEIGHTuncorrected)

PARALLAX - in - ALTITUDE = 8.7 *COS* (27.3369 deg) - (8.7)(0.8883) = 7.7284 deg

HEIGHTuncorrected minus *PARALLAX - in - ALTITUDE = HEIGHTcorrected*

(27.3369 deg) - (7.7284) = 19.6085 deg *ElevationAngle*

Azimuth Angle to Satellite

The azimuth angle is the direction in the horizontal plane that the antenna points towards the satellite. Antenna rotation is in a clockwise direction from true North. The azimuth angle may have any value between zero to 360 degrees. The azimuth angle can be determined from an intermediate value called alpha (α).[4]

Δ equals the difference in longitude between the radio station and the satellite. Lat.is the radio station's latitude.

α = arctan (tanα/sin*Lat*) = arctan (tan 51.55 deg/sin 42.4) = arctan(1.8677) = 61.83 deg

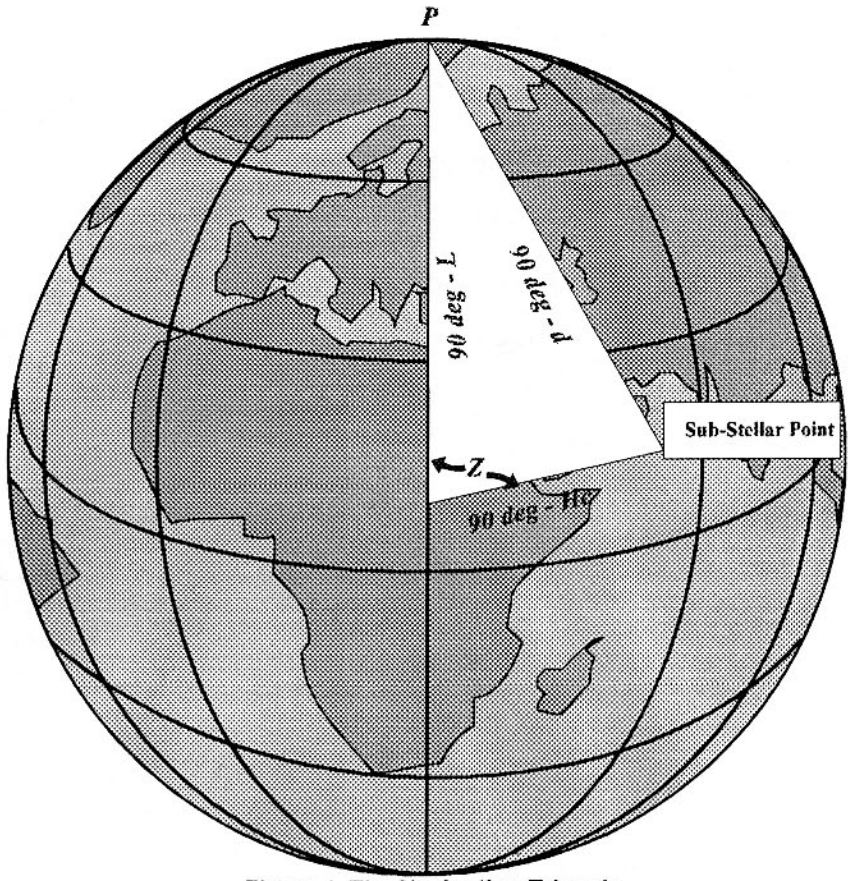

Figure 1. The Navigation Triangle.

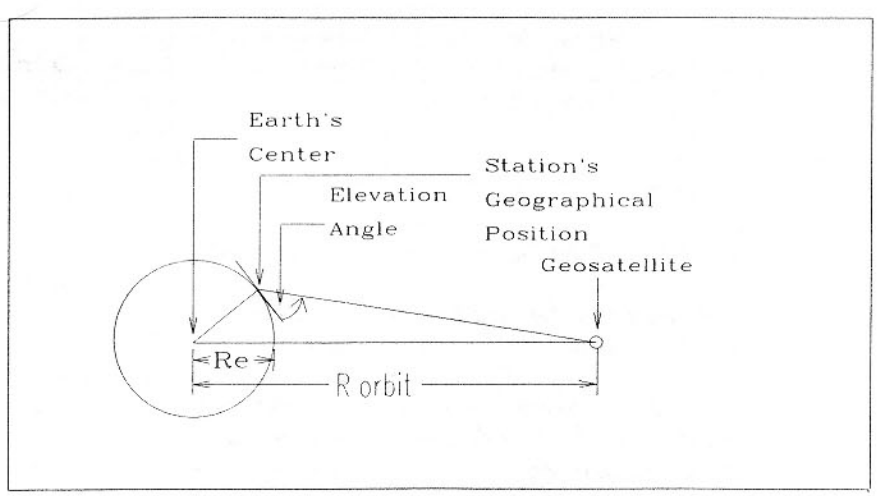

Figure 2. Side view of geosynchronous satellite, and its relation to the Earth (An Obtuse Angle). Elevation angle is measured from plane horizon tangent to the earth's surface, Re=radius of earth, and Ro=radius of Satellite Orbit.

Satellite East of Station Position

NORTHERN HEMISPHERE $Az = 180 - \alpha$

SOUTHERN HEMISPHERE $Az = \alpha$

Satellite West of Station Position

NORTHERN HEMISPHERE $Az = 180 + \alpha$

SOUTHERN HEMISPHERE $Az = 360 - \alpha$

The satellite is east of the radio location in Boston, and in the Northern Hemisphere, therefore:

$Az = 180 - \alpha = 180 - 61.83 = 118.17$ deg

Summary

I have shown a method that can be used to find any antenna pointing angle towards a geosynchronous satellite in the Clark Belt. I have used it with good success with hand held navigation pocket calculators and H.O.249/229 Sight Reduction Publications while onboard ship during many voyages to isolated areas of the world.

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AMSAT Field Ops Update

Barry A. Baines, WD4ASW, AMSAT VP-Field Operations

Editor's Note: To keep our members aware of AMSAT field operations, Barry has offered to write AMSAT Field Ops Updates for the journal. We welcome Barry on board and look forward to publishing future field ops updates in The AMSAT Journal.

Mike Crisler, N4IFD, has relinquished his position as VP-Field Operations and I've assumed the position. Mike has served as VP-Field Operations twice, the most recent being after his family had recovered from the devastation of Hurricane Andrew. Over the past two years he has done a wonderful job in a number of areas, such as leading our exhibit efforts at the Dayton Hamvention and Miami Tropical Hamboree, as well as chairing the 1995 AMSAT Symposium in Orlando, FL. While Mike will continue to support the organization at Dayton and in other ways, I've agreed to handle the task of organizing the field operations effort at AMSAT.

Let me take this opportunity to introduce myself. I have been employed by CSX Transportation since 1981 and currently work in Service Design as Director-Intermodal Scheduling. I have been a Radio Amateur since 1977 and an AMSAT Life Member since 1982. I have manned the AMSAT booth at the Jacksonville Hamfest since 1984 and helped represent AMSAT at Miami, Orlando, and Dayton, Ohio on a regular basis. I attended my first AMSAT Symposium in 1988 and was in charge of registrations for both the 1994 and 1995 AMSAT Symposiums. Most of my satellite activities revolve around digital satellites as I started a satellite gateway node in Jacksonville in 1993. Like other area coordinators, I've given talks on satellites at hamfests and club meetings. I was also a presenter at the first AMSAT-ARRL Satellite Workshop that was held last July in conjunction with the ARRL's New England Convention.

My experience with AMSAT suggests that people who do not have a *technical* background can make a make a difference for AMSAT. Included in this issue of *The AMSAT Journal* is a list (as of February 11) of hardworking volunteers who have agreed to serve as Local Area Coordinators. These people do the kinds of things that I described above—help with hamfests, make club presentations, answer questions, etc. Some have established nets on local repeaters; others have organized local AMSAT gatherings in their areas. While the list appears to be large, you will note that our coverage is weak in a number of areas. The Dakotas, New England, and portions of the Midwest are not well represented. In fact, we don't have a designated local area coordinator for Los Angeles, California! We need volunteers to represent AMSAT on the local level who are willing to work with clubs, hamfests, and other Amateurs and can act as a conduit for information about the satellite program. You are not expected to know *everything* about all facets of satellites. As the field organization develops we are in the process of creating materials and identifying points of contacts that will help individuals respond to questions outside their areas of expertise as well as provide ideas on how we can better *show the flag*.

The *qualifications* for being a coordinator are simple: You must be a current AMSAT member (after all, you're representing AMSAT) and have an interest in representing the organization as your time and interests permit. We also ask that you have electronic mail (Internet) capability. We will be communicating with members of our Field Ops team with e-mail only since it provides an easy and very effective means of distributing ideas and information at relatively low cost.

If you are interested in serving as a Local Area Coordinator, please contact me via:

- E-mail: *wd4asw@amsat.org*
- Telephone: 904-398-5185 (home)
- Facsimilie: 904-346-0192 (home)

AMSAT Area Coordinators

State	Call	Name	Address	City	Zip	Home Phone	E-mail
AK	Vacant						
AL	N4NR	Dennis Dease	2588 Royal Way	Pelham, AL	35124	(205) 733-9975	n4nr@amsat.org
AL	W3PM	Gene Marcus	917 Chatterson Rd.	Huntsville, AL	35802	(205) 880-1237	w3pm@amsat.org
AR	WC5I	Mark Manes	109 Maple Shade Road	Alma, AR	72921		wc5i@amsat.org
AZ	AA7KC	Jim Weisenberger	6502 E. Pebble Dr.	Mesa, AZ	85215-2938	(602) 985-2641	aa7kc@amsat.org
AZ	N7NQM	Gary Duffield	4102 W. Paradise Ln.	Phoenix, AZ	85023	(602) 843-1188	n7nqm@amsat.org
AZ	NW7N	Larry Brown	2721 S. Black Moon Dr.	Tucson, AZ	85730	(520) 886-1957	nw7n@amsat.org
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CA	WB6OVH	Gordon Fuller	7756 Tobia Way	Fair Oaks, CA	95628	(916) 961-0576	wb6ovh@amsat.org
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CO	K9MWM	Bob Ludtke	406 Yale Circle	Glenwood Springs, CO	81601	(303) 945-8722	w0zzq@amsat.org
DE	K3BY	Sam Guccione	110 Chalet Court	Camden, DE	19934	(302) 697-6079	
FL	KB4SYV	Ed Boyett	813 32nd St., W.	Bradenton, FL	34205	(813) 746-5681	kb4syv@amsat.org
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MI	N8QGC	John Sheets	17820 Reno Street	Riverview, MI	48192	(313) 281-4603	n8qgc@amsat.org

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MN	W0QIN	R. Clark	7701 Glasgow Drive	Edina, MN	55439	(612) 944-1315	w0qin@amsat.org
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NM	WA5WHN	Jay D. Miller, III	4613 Jupiter, N.W.	Albuquerque, NM	87107-3944	(505) 662-2011	
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PA	KC2FU	Robert Haitmanek	RD1 #1420A	Bangor, PA	18013	(610) 588-9878	
RI	Vacant						
SC	KB4BKH	Michael D. Katz	911 4th. Ave. N. #4	Myrtle Beach, SC	29577	(803) 946-6892	
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VA	KC4TZN	Mark Satterfield	1105 Rittman Road	Virginia Beach, VA	23464-5929	(804) 495-0598	
VA	KM4EM	Charles A. Richard	2301 Jefferson Davis Hwy, #1512	Arlington	22202	(703) 418-0234	km4em@amsat.org
VA	WY4D	Ben A. Hall	836 Ridgecrest Drive	Roanoke, VA	24019	(703) 366-1340	wy4d@amsat.org
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WI	N9UUR	Gary S. Bargholz	8273 N 53rd	Brown Deer, WI	53223	(414) 355-6922	n9uur@amsat.org
WV	Vacant						
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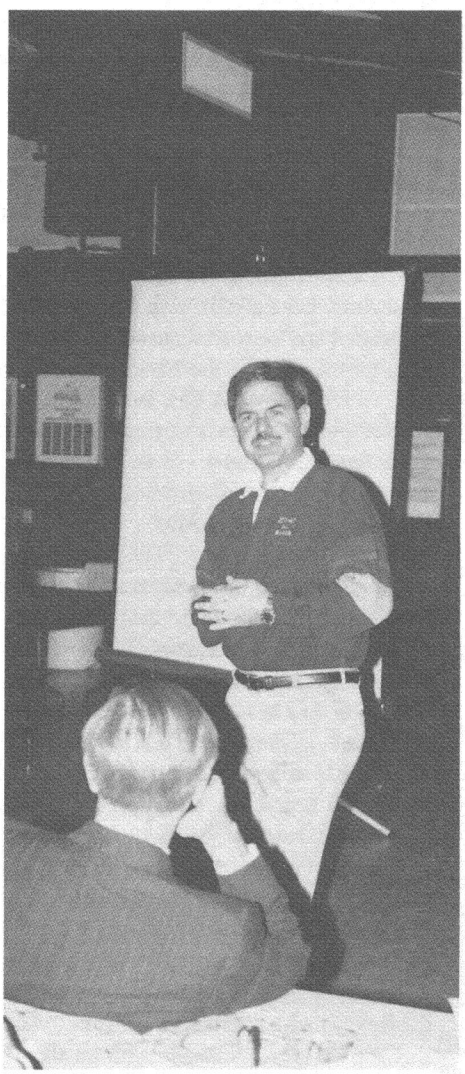
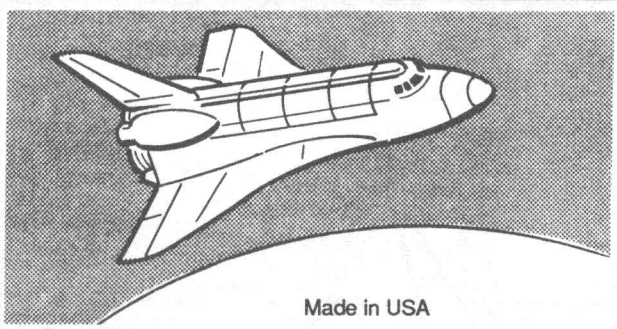
CAN	VE7VVW	Ron Sieler	4001 15th Crescent	Vernon, BC	V1T7HS	(604) 545-3124	
CAN	VE7XQ	Tony Craig	20691 - 45A Ave.	Langley, BC	V3A3G3		



Ron Parise, WA4SIR recently provided the Goddard Amateur Radio Club with a presentation on SAREX activities on his STS-67. (Roberto Aleman, N3QVD)

AMATEUR TELEVISION



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SEE THE SPACE SHUTTLE VIDEO

Many ATV repeaters and individuals are retransmitting Space Shuttle Video & Audio from their TVRO's tuned to Spacenet 2 transponder 9. Others may be retransmitting weather radar during significant storms or home camcorder video. If it is being done in your area on 420 MHz - check page 538 in the 95-96 ARRL Repeater Directory or call us, ATV repeaters are springing up all over - all you need is one of the TVC-4G ATV 420-450 MHz downconverters, add any TV set to ch 2, 3 or 4 and a 70 CM antenna (you can use your same 435 Oscar beam). We also have downconverters and antennas for the 902-928 & 1240-1300 MHz bands. In fact we are your one stop for all your ATV needs and info - antennas, transceivers, amps, etc. **Hams, call for our complete 10 page ATV catalogue!**

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A Recommendation for Doppler Tuning

by Ron Parsons, W5RKN, w5rkn@amsat.org

Because a satellite is moving relative to your fixed ground station, the frequency of the satellite's transmission is raised or lowered due to an effect called the Doppler shift. This is the same effect that causes you to hear a train locomotive's horn at a higher pitch when it is coming toward you and a lower pitch as it moves away. Similarly, a radio signal from a satellite is received at a higher frequency as the satellite is approaching you and at a lower frequency as it moves away.

The Doppler shift is proportional to both the radio frequency and the instantaneous velocity. For many satellites, this effect can be quite large. For example, the downlink signal from FO-20, a low-earth-orbit (LEO) satellite whose transmitter is in the 435 MHz band, can have a total Doppler shift of 18 kHz from the beginning to the end of the pass. Not only is the total shift large, the rate that the Doppler shift changes can exceed 30 Hz each second. This requires you to tune your receiver constantly just to keep the SSB signal intelligible or to keep the CW signal within the receiver's passband.

Because the satellite is moving toward or away from each ground station at a different rate, all parties in a QSO will experience different Doppler shifts for each station. Two-way QSOs can be managed by careful manual tuning, but three-way QSOs are very difficult. All this tuning detracts from the conversational aspects of the radio contact.

The most common rule suggested for Doppler compensation with amateur satellite transponders is for both stations to keep the lower of the two frequencies (transmitter or receiver) fixed. As can be seen from Figure 1, this rule does not work well because the rate of change of the Doppler shift is not the same for both stations. This leads to many QSOs being preoccupied with conversations about being off frequency.

Martin Davidoff, K2UBC, in his book *The Satellite Experimenter's Handbook* recommends that the station farthest from the bird establish a reference frequency by keeping the lower of its transmit or receive frequency constant during the contact. All other stations tune their frequencies to that station's reference frequency. This is a minimal improvement since all but one station must also tune the lower frequency.

I am advocating a change in the Doppler compensation method to one in which both the transmit and the receive frequencies are held fixed *at the satellite transponder*. This method is especially useful on satellites where the Doppler shift is large and/or rapidly changing, such as LEO satellites and AO-13 Mode S. It will become increasingly important for Phase 3D as we move the most-used operations higher in frequency. Paul Williamson, KB5MU, discussed this method of Doppler tuning in the lead article in the January 1, 1994 issue of OSCAR *Satellite Report*. He called it the One True Rule and defined it as tuning "both the transmitter and the receiver to achieve a constant frequency at the satellite." He went on to state that "if everybody did this, there would be no problem with everybody staying together on the same frequency, and there would be no drift through the passband." I will call this method *Full Doppler Tuning* or *FDT*.

This method requires that all stations continuously adjust both their transmit and receive frequencies, but, as can be seen in Figure 2, all stations hear each other at the same spot on the dial as they hear their own echo. This is the tremendous advantage that this method has over all others. If each participant in the QSO is using FDT and hears his own echo clearly, all participants in the QSO will hear *everyone* clearly. If you have not experienced this, you will be pleasantly surprised with the improvement it makes.

This method also provides a common frequency that all participants share. I will call this the *Satellite Frequency*. It is the fixed downlink frequency, measured at the satellite, of all participants in the QSO. This is the frequency at the satellite transponder where all the lines in Figure 2 cross. Remember that the Doppler

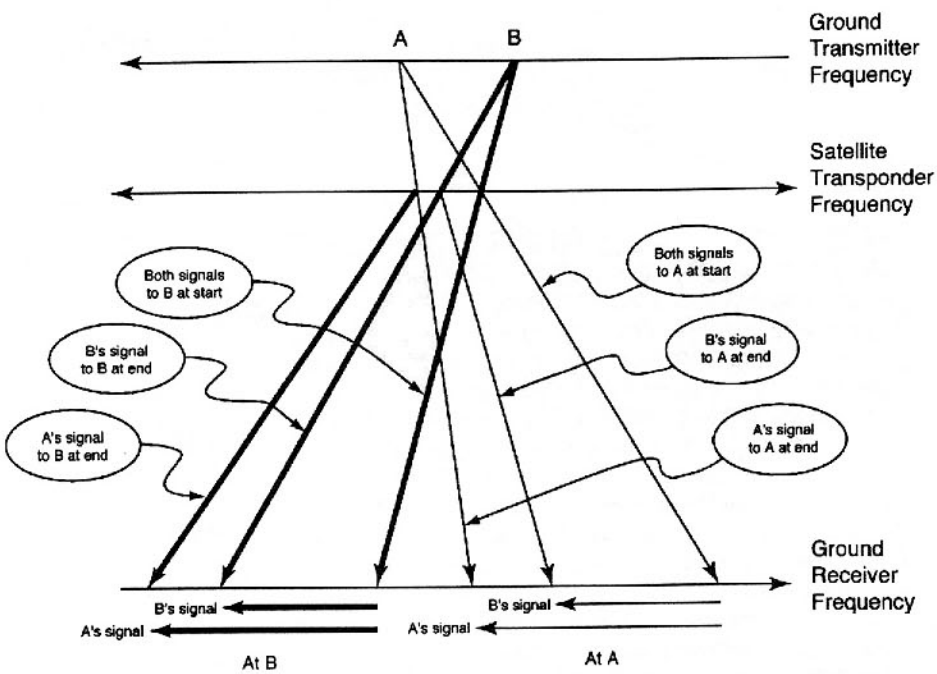

Figure 1

An illustration of a Mode J (V-U) contact from start to end where both stations (A&B) hold their transmitter frequencies constant. The thin lines illustrate the signals arriving at location A, while the bold lines illustrate the signals arriving at location B. Note the unequal drift of each station's signal at the receiving locations (the horizontal arrows show the total drift of each signal from start to end). Note also that signals from both A & B drift along the satellite's transponder passband.

effect causes the frequency of the received downlinks to be different from the Satellite Frequency. The FDT algorithm adjusts both the transmit (uplink) frequency and the receive (downlink) frequency such that the two frequencies as measured at the satellite are constant. They do not drift within the satellite's passband as the Doppler shift changes throughout the QSO. Because both uplink and downlink frequencies are changing, and changing at different rates, the only practicable way to accomplish this is by use of computer control of the transceiver frequencies.

Paul's article also noted that the computer should be able to control the transmit frequency automatically as the receiver's tuning knob is turned. The implementation should be transparent to the user. Transparent means that the radio should be the center-of-control for satellite operation rather than the computer. After all (I keep telling myself) ham radio is a radio hobby, not a computer hobby. One should be able to tune around the satellite's passband with the radio's tuning knob and not worry about the Doppler compensation problem. As you tune the receiver, the transmitter frequency will be adjusted by the computer so that your "echo" from the satellite is kept at the frequency of the receiver.

Of the more popular satellite rigs, the Icom (IC-970, IC-820, IC-275/475) and the Kenwood TS-790A have the necessary computer-control commands to implement FDT in a transparent way. Unfortunately, the Yaesu FT-736R does not. It does not permit the computer to "read" the dial of the radio. A partial solution to this problem will be discussed later.

My use of FDT began shortly after Paul Williamson's article was published. I had developed a Macintosh-based satellite control program, MasterControl (see Note 1), which implemented a variety of Doppler tuning methods. I took Paul's article as a challenge and included the FDT Doppler compensation method in my program. I also added the desired transparency capability so I could tune the receiver of my IC-970 while speaking into the microphone. The transmitter frequency is automatically adjusted so that the echo from the satellite is kept right on the receiver's frequency, even for satellites whose Doppler shifts change rapidly such as FO-20 and Mode S on AO-13. Unfortunately, there are very few other hams that control their satellite radios with a Macintosh, so I had very few opportunities to test the operational effectiveness of FDT.

Recently a DOS-based program has become available that implements FDT and the transparency capability. This program is Nova 1.1 by Michael Owen, W9IP (see Note 2). Nova will tune the transmitter and receiver in various modes just as MasterControl does. If you tell it to compensate for Doppler shift on both the transmitter and receiver, it implements FDT. It can also implement transparency so the receiver's tuning knob can control the transmitter. I have worked a number of stations using Nova on FO-20, including 3-way QSOs.

If you are using an Icom or Kenwood radio and manually tune the receiver, Nova will adjust the transmitter frequency to keep the uplink and downlink signals in sync. Nova also provides a capability for Yaesu FT-736R owners to use the FDT method with transparency. It does this by providing two tuning 'knobs' on the computer screen that can be turned with a mouse to tune the transceiver.

Theory aside, how well does this method work in practice? I can answer that with a resounding "Very Well!" I have had a number of QSOs on FO-20 that have lasted for nearly twenty minutes without either station touching the transceiver dial. They were using Nova and I was using either Nova or MasterControl. Changing frequency to get away from QRM was as simple as "move up 3 kHz" and when you retune your receiver to hear the other station, your transmitter is automatically brought right on frequency. Best of all, 3- and 4-way QSOs are now easy. With all stations using FDT, the stations do not drift apart due to their diverse Doppler shifts.

Stations using FDT drift more on the downlink than do stations keeping their transmitter fixed and tuning their receivers (this assumes mode JA or similar modes where the transmitting frequency is the lower frequency). For example, with a maximum Doppler shift on 145 MHz of about 3 kHz (typical for FO-20), keeping the transmitter fixed will cause the downlink receiver frequency to shift down by 12 kHz during the entire pass. With FDT tuning, the corresponding shift in the downlink receiver frequency is 18 kHz. Thus, to avoid FDT stations colliding with stations using (currently) conventional tuning, FDT stations should start higher in the satellite's transponder passband.

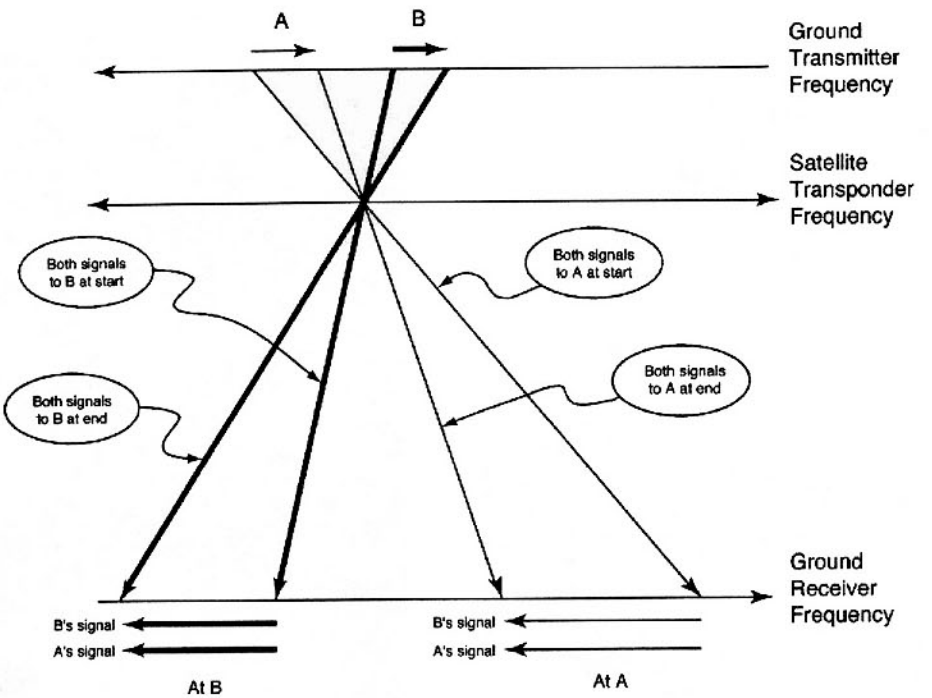

Figure 2

An illustration of a Mode J (V-U) contact from start to end where both stations (A & B) are using Full Doppler Tuning (FDT). The thin lines illustrate the signals arriving at location A while the bold lines illustrate the signals arriving at location B. Note that the transmit and receive frequencies of both stations change from start to end by different amounts. Note also that the frequencies of both A & B at the satellite are constant and equal and do not drift along the satellite's transponder passband. Because of this, signals from both A & B track together at each location.

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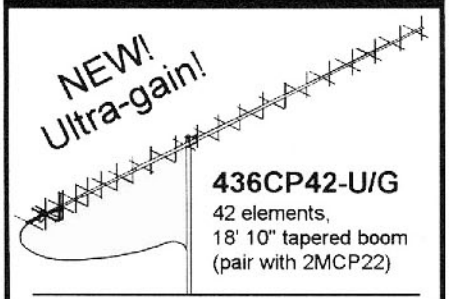

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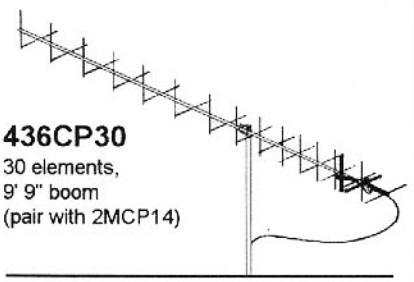

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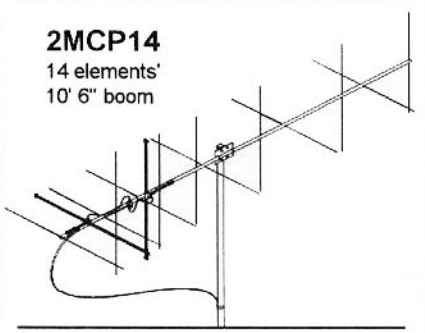

2MCP14
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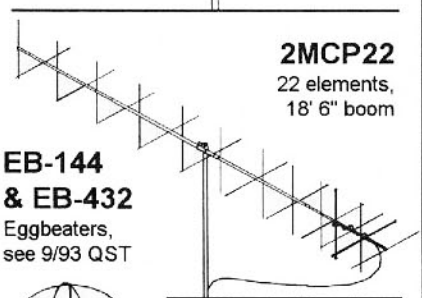
10' 6" boom



2MCP22
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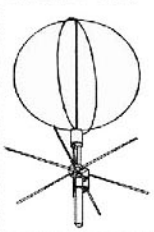

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To encourage stations to use FDT, I would like to propose an informal sub-band for QSOs using this method. Because of the downshifting discussed above, this sub-band should be high in the satellite's passband. I have noticed that for most satellites the upper 25% of the satellite's passband is much less heavily used than the center 50%. Therefore I propose that stations using this method and looking for others also using this method should congregate in this upper 25% of the passband. This corresponds, on FO-20, to receive frequencies 435.875 to 435.900 MHz.

Of course, this frequency specification should refer to the *Satellite Frequency*, not to the actual receive frequency. Both Nova and MasterControl provide a way to display the Satellite Frequency. That way, if you wish to set up a schedule with someone, you could say "Meet me at Satellite Frequency .880" Both operators can set their transceivers and meet each other right on the button without hunting around to figure out how Doppler shifts have affected each station. I can assure you that this procedure works extremely well. I have met schedules and have had my transceiver set exactly right, even before I heard the first transmissions from any of the other stations.

If you can use this method of Doppler tuning, do try it. I think you will find it well worth your trouble. You can tune around the band and forget the Doppler shift. It's just like working the HF bands without all the QRM. Satellite operating becomes a real pleasure. ■

Notes:

1. More information on the Macintosh MasterControl program can be obtained from the author. The program requires the Mac OS System 7 and has been tested extensively on Icom transceivers. Testers are being sought for Kenwood and Yaesu transceivers. It controls the transceiver frequencies using a serial port, controls the antenna orientation using the Yaesu G-5400B rotator and the Yaesu GS-232 controller, and uses an X-10 controller to switch antenna relays, etc. It requires additional serial ports to use all the features but the user can ignore features not desired. Ongoing support is available but no commitment is made.

2. Nova 1.1 program can be obtained from Bob Myers Communications,PO Box 17108, Fountain Hills, AZ 85269-7108, voice: 602-837-6492, FAX: 602-837-6872, e-mail: *bmyers@primenet.com*, WWW: *http://www.primenet.com/~bmyers/*

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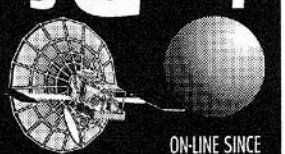

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Donors To AMSAT-NA Phase 3D Funds Campaign (Part 1)

November 1, 1991 to February 19, 1996

Bob Carpenter, W3OTC, Phase 3D Fund Raising Campaign

Editor's Note: This is the first of a two-part series that identifies AMSAT-NA Phase 3D donors. Part 2 will be published in the next issue of The AMSAT Journal.

The AMSAT-NA Phase 3D Funds Campaign got underway in November 1991. Since that time over 2500 individuals and clubs have contributed over $500,000. The Campaign established donation levels which could be achieved by yearly or lump-sum payments. Many have completed five-year pledges, although some joined the Campaign later and will complete their pledge in 1996. A final list will be published later.

In addition to the donors listed below, there were some notable large contributors. The Hoover Foundation provided over $100,000 in matching funds. AMSAT-UK contributed over $76,000. The American Radio Relay League conducted its own Phase 3D campaign on behalf of AMSAT-NA, providing over $160,000 to match its donors, for a total of over $320,000 in 1995. During the 1993 the ARRL conducted a similar campaign and provided about $200,000. The J. C. Downing Foundation donated $15,000 and an anonymous foundation donated $10,000.

Also not listed is the roughly $45,000 that Phase 3D has collected in donations for the SATSKED, WiSP, and WINSAT tracking programs. These programs were donated for the benefit of Phase 3D by their respective authors: WA2N, ZL2TPO, and KA7LDN.

AMSAT and the Phase 3D project depend on people. We owe special thanks to those who have donated thousands of hours of their time and skills instead of money.

Donors are listed in decreasing order of total donation. Those with equal donations are listed in inverse alphabetic order. Those who have notified AMSAT headquarters of a donation of $36.92 or greater to the 1996 ARRL Phase 3D campaign are marked with an asterisk.

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DARC Contribution to Phase 3D Completed:
A Total of 900,000 DM ($600,000) Raised

Norbert Notthoff, DF5DP
DARC Staff Satellites And Space Projects

In 1991, the Deutscher Amateur Radio Club (DARC) signed an agreement with AMSAT-DL in order to support the Phase 3D project with 150,000 DM per year over a period of six years to a total sum of 900,000 DM. The DARC is the national German amateur radio organization within the IARU and represents nearly 60,000 German Radio Amateurs.

In 1991, the DARC General Assembly had agreed to provide major support to Phase 3D, which is being considered to be an important project for the whole Amateur Radio Service. This project demonstrates the state of the art of Amateur Radio as a means for technical development and self education. Additionally Phase 3D will promote usage of the Amateur Radio microwave bands, which are under high pressure from other services. These are the main reasons why the DARC General Assembly decided to support the Phase 3D Project with about $ 10 per member.

In recent years it turned out that the decision to support Phase 3D was very wise, because there are now many threats against the Amateur Radio Service, not only in Europe. Meanwhile, DARC welcomes national IARU member societies support of the AMSAT groups with donations for Phase 3D.

DARC's first contribution was made in 1990, and the last (sixth) for 1995 brought the total sum to 900,000 DM (approximately US-$ 600,000)! We are proud that we could help the Phase 3D Project with this substantial contribution.■

PY2AJK, N9JKP, N8QMD, N7QOC, KI5OI, KD6RCX, KC2FU, KB5DXB, KA3VGD, KA3QKV, HB9MSM, KA1IU, WA6OPB, N3JNX, WA1ZVA, WB5FCO, NC5Y, KE7WR, WD4MBK, Burlington A.R.C., KI4FN, K4SCL, W1BIH, K9BPT*, W3QBC, I5BAK, WA6WJA, F6BKI, XE1KK, WH6I, WD9ICG, WD5FFH, WD5EEV, WD0HHU, WB8SBI*, WB6CNO, WB5TKI, WB4AKK, WB2KDO, WB0KIZ, Ward French III, WA9UZK, WA9AFM/5, WA7ZVY, WA6LXB, WA6EWV, WA5HNK*, WA4WDL, WA4PLR, WA2KLZ, WA2GWW, WA1NHP, WA1GRC, W9QEZ, W8IMF*, W7MCU, W7LHI, W6SJZ, W6RRK, W6LLP, W6GGM, W6EX, W5SBH, W5AL, W4YDH, W4RDI, W4PUJ, W4IXN, W4DVJ, W3HJD, W3HFY, W3GYK, W3GH, W2SBI*, W2PTZ, W2/JE1FXT, W1RZB, W1HMS, W1ECQ, W0PN, W0OQC, W0KSD, W0CD, VU2GV/A22GV, VP9C*, VK3DTO, VE7YQ, VE7XJC, VE7VVW, VE7LDH, VE5VP*, PY3OB, PY2DBU, PJ2CAI, P43BB, OE1JIS, NY0D, NN0J, N9VLK, N9LTD, N9CCE, N8SPX, N8DDV, N8CBU, N6IK, N6AVB, N5XPD, N4UFP, N4PTS, N4CU*, N1KUK, N1AXB, N0KMA, LU5ALG, LU4EBC, KR2C, KO4WC, KL7IFX, KL7GRF/6, KK6PH / AA6XZ, KK4FI, KF0JT, KE6DPE, KD7XP, KD6WW, KD4RPK, KD4HSL, KC6TFN, KC4TDA, KC4MWL, KB7VE, KB5THX, KB0TZO, KA6M, KA6KIQ, KA0YOS, K9VCM, K9ATR, K8UIW*, K8PNW*, K8OCL, K8LIX, K8BGZ, K7JRA, K6QXB, K6IS, K6GSJ, K5YVF, K5PER, K5GM, K5ADQ, K4EDU*, K4CAV*, K4ADK, K3CLG*, K2KNW, K1RT, K1COS, K0ZD*, JN2AMR, IW0EAC, IK0FAX, I1TEX, HB9RM, HB9MZZ, HB9BWN, HB9AOX, G7EDI, FO5KF, F6ADZ, ERIC ARCHER, Digital Equipment Corp, Carl Flahaven, BV4AS, BV1AF, bd Systems Inc., Alamo DX Amigos, AL7KD, AL7FS, AC4GP, 7J1AJH*, N8HRC, WB4GZX, WA8SHC, WB5MPU, AA5PR, W9KFB, W8AH, VE3OYT, N0JAR, K4QJP, WA5QGD, N3AMF, KB0EMR, I1YS, WA3AEE*, K6DUX, WG0I, WD8LAQ, KB5KJ, W3LUI, W5LQD*, KD1PK, AA2BN, W6VVD, N1KCE, WA3YER, WA0PXW, W2XI, KA8HHU, K2EII, IK4HDO, WA4ZZU, IK1PKH, WD0ELL, N8AM, N5QGT, N2OTD*, KN4CG, KA5VJB, HB9VAL, DL5KR, W6WFW, N6AFT, AB6DT, WA8NPX, W8RAK, So Milwaukee A.R.C., KR0U, KK5DO, HB9SUA, ARI Valcamonica, WB4UUE, W7KOP, W2KIY, VU2MY, N8IFU, N4QQ*, KN6OH, W0DEL, K6MGM, K1DS, WB8CKI, W0EKZ, KE3SU, WZ9T, WD8NNG, WB8VBW, WB5TGL, WB4QHM, WB4AXQ, WA9SKG, WA9MTO/3, WA4TNV, WA4FHY, W8WN, W6WBK, W5SEP, W4XT, W4NG, W4LYZ, W3UJG, W2YLV, W0IAK, VK5EU, VK2ZIS, VE7EGO, VE7BCM, VE7ASP, VE6SY, VE6KY, VE6CNG, VE3WWS, VE3SPF, VE3CJE, VE3BNO, THOMAS O. JELKS, JR, ROBERT A. PAYNE, JR, OH1QK, NW0X, ND6G, N9EZV, N8PHK, N8OZB, N7IJB, N5DIB, N4NPV, N4EKS, N3HKQ, N2PPL, N2NMW, N1LHW, N0UU, LU1BEE, KO6HK, KJ4IY, KH6IJ, KH6GPI, KG7FV, KE8UM, KD6FDK, KD0MA, KC4JYR, KA9CND, KA3QKI, KA2GDS, K9JMA, K5LLL, K4QNF, K0VVW, K0ES, Joaquin Marti Marques, IK0DJE, HB9SUK, Gregory Waits, DD2XB, CT4KQ, ARI Sezione di Torino, Anthony E. Meyer, AC4FN, 7J1AKH, XE1OE, WD9HGO, WB6YDE, WB6VRN, WB6LLO, WB4MOY, WB4MOX, WB0YNH, WB0SMX, WA9BST, WA6LXW, WA6JEY, W6UPI, W6JNU, W4EAT, W4AET, W1YCW*, W1WXZ, VK7KP, PY2AUC, N9JWF, N8LGE, N5TD, N3NG, N3BOB, N2NFI, N0IYN, KL7BT, KG7CC, KE5SA, KD2Q*, KB5JRA, KB4NUC, KB2EZE, KB2CKN, KA9GLX, KA6MSR, K9JA, K6UI, K6KTS, K5HGX, K5CF, IK8GYQ, AL7HF, AF9A, AA5PA ■

AMSAT-France Phase 3D Donations

Bernard Pidoux, F6BVP *(f6bvp @ f6bvp.frpa.fra.eu)*

On February 23, 1995, Vincent Magrou, F5JFT representing the REF Union at IARU, welcomed an AMSAT delegation including Bill Tynan, W3XO, President of AMSAT-NA, Vice President Dick Jansson, WD4FAB and Peter Guelzow, DB2OS from AMSAT-DL at their Tours REF headquarters located 230 km south of Paris. Also present were Gerard Auvray, F6FAO and Bernard Pidoux, F6BVP, Vice Presidents of the Radio Amateur Club de l'Espace (RACE) and three representatives of the Club Aerospatial de la Celle Saint Cloud (CAC); Christophe, Yves and Christophe, who are all awaiting for a callsign after having successfully completing their novice Amateur Radio examinations. Members of CAC, RACE and DELTAC, a third club interested in space telecommunications have decided to create AMSAT-France in order to promote activity in the field of Amateur Radio satellite service in France. During the meeting DB2OS was presented a 30,000 FF (approx $6,000) check by Jean Marie Gaucheron, F3YP, REF Union President representing a donation from REF to Phase 3D project. In addition, RACE gave WD4FAB, two models of the L band antenna reflector for Phase 3D. They are composed of a 500 mm disk with a straight 78 mm border all in one piece without soldering and manufactured using a special process. These antennas have been supported by RACE and constructed by a company near Bordeaux with the help of Radio Amateurs from the Club Jeune Science. These contributions were made by AMSAT-France in order to significantly and effectively contribute to the Phase 3D satellite project. They follow $2,700 of individual Phase 3D donations from French Radio Amateurs recorded by AMSAT-NA. AMSAT-France hopes that she will be receiving more contributions in order to help successfully achieve Phase 3D's potential

Si tous les gars du monde voulaient se donner la main...

AMSAT-UK

Announces a program to put YOUR CALLSIGN in SPACE

Yes! Your callsign can fly on Phase 3D when it roars into space next year. The British AMSAT group has arranged for the inscription of amateur callsigns, or the names of individuals or corporations, on a plate in the Phase 3D spacecraft.

By taking part in this exciting program, you will not only assure your lasting presence in space, receive an engraved personal trophy, and help insure the completion and launch of this wonderful new amateur satellite.

To make it even easier for those in North America to participate, AMSAT-UK has appointed an agent in the U.S. to receive contributions.

To have YOUR callsign fly on Phase 3D, send a check for $250 ($400 for clubs), in U.S. currency, made payable to:

Eric Rosenberg WD3Q
3511 Patterson St. NW
Washington, DC 20015

Please mark it: "AMSAT-UK Calllsign in Space Contribution"

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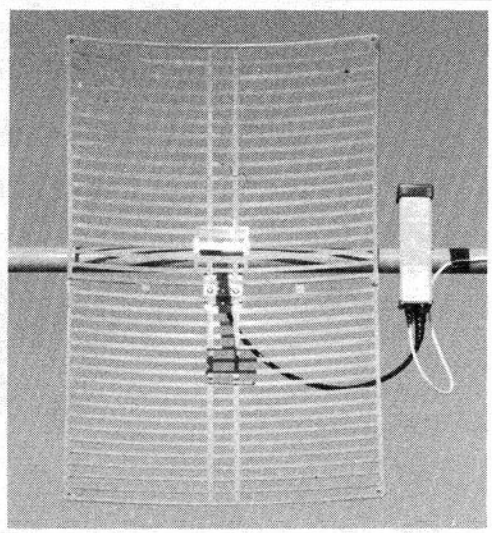
**Publication prices USA only. Others please call.*



New for Dayton this year: HF Monoband Vertical/Groundplane antennas. Heavy Duty! Teflon insulated inductor, 2500 watts. Models for 160 meters, 80 meters, 40 meters, 30 meters. Two versions: short and tall. Best antenna for DX (unless you have a Yagi on a high tower with rotor!). Also monoband 30, 40 and 80 meter rotating dipoles (approx. 44 feet long). Spec. sheet and photos available May 1, 1996. Call/FAX/email. http://www.primenet.com/~bmyers

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Visit us at the Dayton Hamvention, May 17-19, Booths 464-465. Email: bmyers@primenet.com

RULES FOR USING THE AMSAT OSCAR QSL BUREAU

1. The AMSAT QSL Bureau serves the users of all amateur radio satellites with a complete QSL Bureau for all amateur radio satellite contacts (QSLs other than satellite QSOs will be returned).

2. Stations wanting to use the Bureau need only to send three to six #10 S.A.S.E.s (one unit of postage) with your call in the upper left hand corner. DX stations should include enough IRCs for each envelope on file!

3. To send your cards through the Bureau, arrange the cards ALPHABETICALLY by call sign. Stateside cards are free. However, there is a charge of 10 cents per card for all stations outside the U.S. Postal districts.

4. Always keep the Bureau informed of any changes in your address or call sign. If you have worked stations with more than one call sign, you should send envelopes for all call signs.

5. Mailings from the Bureau will be at the end of each month. All envelopes with ANY cards will be mailed at this time. The only exception is if the amateur would like to have their envelope held for a certain number of cards before being mailed. This can be done by writing just below your call sign (in the upper left-hand corner) the number of cards desired in the envelope before it is mailed.

6. QSL cards that are received at the Bureau when there are no envelopes on file will be held and the Bureau will make an effort to notify the user that he/she has cards on file. If no envelopes are sent to the Bureau within a period of 6 months, the cards will be DESTROYED!

7. Mailings for DX stations and individual international QSL Bureaus will go out at the end of the month.

8. OSCAR users should also keep envelopes on file at their ARRL QSL Bureau: most DX cards come to them.

9. Questions about the AMSAT OSCAR QSL Bureau should be sent with an S.A.S.E. to the address below:

Walt Rader, WA3DMF
QSL Manager

AMSAT QSL Bureau
3702 Allison Street
BRENTWOOD MD 20722

XR0Y/XR0Z DXpedition to Easter Island
September 1995 - Satellite Operation

Max Bachi, XE1XA

"In the middle of the Great Ocean, in a region where no one ever passes, there is a mysterious and isolated island; there is no land in the vicinity and, for more than eight hundred leagues in all directions, empty and moving vastness surrounds it. It is planted with tall monstrous statues, the work of some now vanished race, and its past remains an enigma." - Pierre Loti, Easter Island, 1872

When Luis Chartarifsky, XE1L invited me to set up and operate an amateur satellite station on Easter Island, I instantly recalled two things from my teenage years. The first was a book with exotic drawings from Pierre Loti, and the second was Thor Heyerdahl and the Kon Tiki Raft making a landing at Anakena Bay, on his second trip to Polynesia. Having those memories, I knew that I could not miss the opportunity to be in a place like that at least once in my life.

Easter Island, locally named Rapa Nui, is now Chilean territory, and is located in the South Pacific Ocean, about 3,800 km from the coast of Chile and 4200 km from Tahiti, making this land among the most isolated inhabited places on Earth.

Around 500 AD the inhabitants started to carve the volcanic rock at Rano Raraku quarry and erected hundreds of huge monolithic statues, called Moais. Many of these statues weighing more than 80 metric tons, are scattered around the island. Some stand alone while others are arranged in rows of up to fifteen. The monoliths are located several kilometers away from where they were carved. In about 1500 AD he carving of Moais suddenly stopped, and about 300 remain in the process of being carved. No one knows what happened to the people who made these statues or why their manufacture was abandoned. It is still a mystery; more than 350 years after Jacob Roggeveen was the first European to visit this remote land.

Cordell Expeditions, a non-profit scientific research group based in Northern California, planned our multipurpose, multi-disciplinary expedition to Easter Island (EI) and Salas y Gomez (SG), a small uninhabitated island located 450 km Northeast of Easter Island. As planning progressed, Cordell obtained all of the permits required by the Republic of Chile, surveyed the area to choose the best place for setting up a fully equipped, self sufficient camp, and sent the necessary equipment to Easter Island and Salas y Gomez.

Our DXpedition involved six independent radio stations which operated from September 5-21, 1995 at La Perouse camp site on Easter Island. The operation conducted research on radio science during a sunspot minimum and implemented a few new DXpedition activities. These included:

- Continuaous operating radio beacon on the HF bands.
- Internet connection.
- E-mail QSLs.
- Next day QSLs.

This article will focus on amateur satellite activity. Articles in other publications will explore HF operations and other DXpedition activities. We hoped that our operation would provide significant interest in satellite operation since we would be operating from one of the rarest countries via satellite. We realized that Japan and Central Europe would have very limited windows during which communication with us would be possible. We therefore planned our operations to include as many of those times as possible.

Our satellite station included an FT-726R multi-band, multi-mode transceiver, with mode A, B, and J capabilities, Gasfet preamps and solid state power amplifiers; providing up to 100 Watts output. The equipment could be powered by either a 12 volts DC car battery

or an AC power source. All the equipment was enclosed in a medium size aluminum suitcase filled with foam, as shown in Figure 1. The antennas for mode B operation were high gain circular polarized yagis, 20 X 20 elements for the 435 MHz uplink and 7 X 7 elements for the 145 MHz downlink. Both antennas could be switched between LH and RH polarization. The mast was a modified TV mast, capable of free rotation both in azimuth and elevation. The rotators are of the old reliable *Armstrong* type, similar to those used in the successful XF4L DXpedition in 1989. The elevation rotator was made with some rope and a marine cleat to tie the rope in order to keep the elevation angle steady. This system was adequate for a high orbiting satellite since frequent aiming is not required. We never missed a mechanical rotator during the operation. Antennas, mast and accessories were packed together in a compact custom made cylindrical carton pipe (Figure 1). Setting up the station and the antennas took less than two hours, thanks to the practice acquired during the preparation work.

With the high gain antennas we had plenty of spare ERP to work the satellites even before the computed AOS and after apparent LOS. Sometimes we had an outstanding S/N ratio with only 4 Watts. Polarity switching capability often made a big difference with weak signals.

We logged 431 contacts from 41 different DXCC countries on AO-10 and AO-13, from September 5th through the 14th. During pileups, we employed split frequencies, and although satellite operators are not accustomed to that procedure, we found it an excellent practice. We had enough time to work most, if not all, of the satellite stations that were sharing a common window with our location, exchanging true RST reports and providing Gridsquare locations, working conditions, and other information about the expedition and the island when requested. We expected good reception considering the low level of man-made noise on a remote island, but we shared the operating tent with two HF CW stations equipped with Alpha 91B HF amplifiers and a 6-meter 1 KW, all powered by a common AC generator. So man-made clicks plus spin modulation from AO-13 attitude made copy difficult at times. We received many good comments and support for the operation, and we are glad we kept most of

Figure 1. XR0Yportable satellite operation equipment and antennas ready for operation

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the satellite operators happy. At the same time, we had the opportunity to add Oscar satellite operation to a top quality DXpedition, confirming the potential of a low power satellite station capable of communicating world-wide.

In our opinion, and for many reasons, Oscar satellites are actually and unfortunately under-utilized, especially in the southern hemisphere, where finding an active station is sometimes very difficult. When the satellite footprint only included South America or the South Pacific, we could only find stations during the late evening hours.

Finally, I would like to give my thanks to Cordell Expeditions, with a special acknowledgement to Bob Schmieder, KK6EK and Carlos Nascimento, NP4IW, who made this expedition a success, and to Nellie Saltiel del Lazard, XE1CI and Luis Chartarifsky, XE1L, my fellow friends from Mexico, and to the large group of international expeditioners who shared their knowledge and friendship.

We would like to receive QSLs via the DXpedition Manager, Mary Ann Crider, WA3HUP, who I also thank for her wonderful assistance.■

73 & DX de: XE1XA, Max.

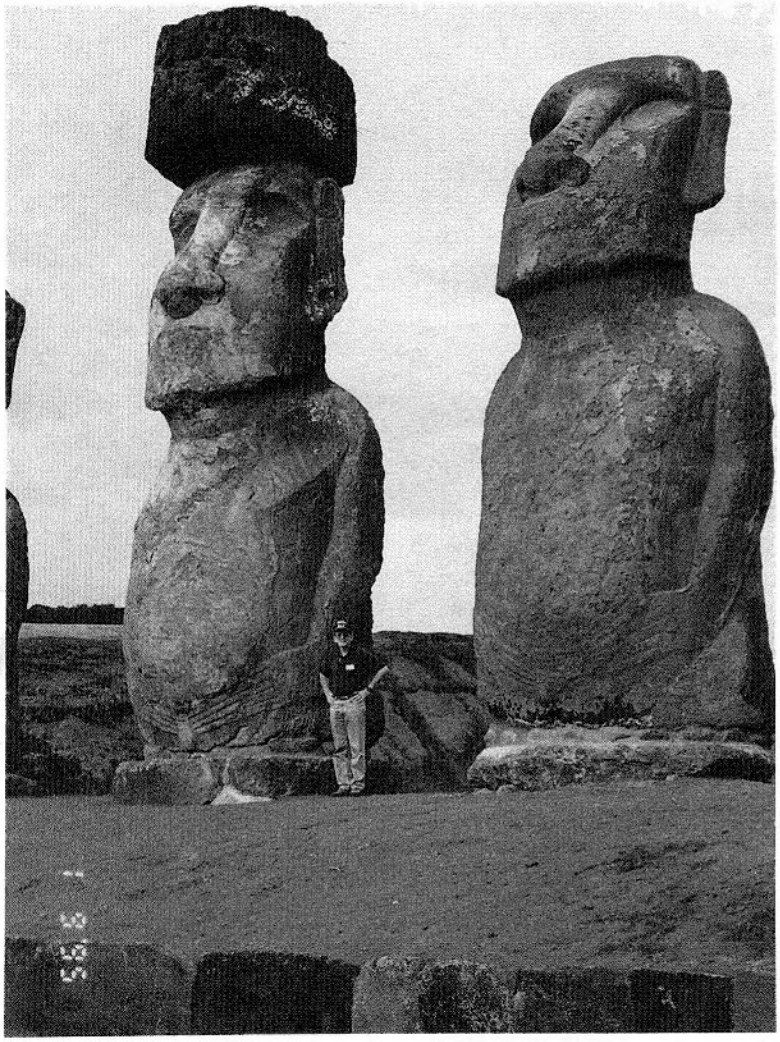
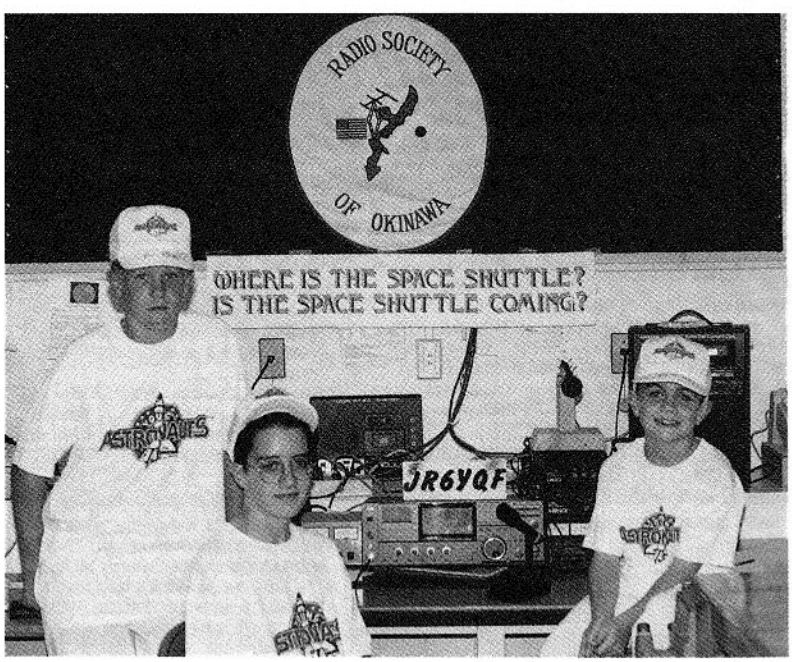


Figure 2. The Moais at Ahu Tonga-Riki, with XE1XA



Young Astronauts (left to right) Jeremy Bosken, Richard and Paul Whalen at Radio Society of Okinawa SAREX station JR6YQF, Lester Middle School, Okinawa. (Photo by Larry Bishop, 7J6CCM)

Lester Middle School STS-74 SAREX Contact

Lester Middle School, a school for U.S. military and civilian dependents in Okinawa, made a successful SAREX contact with STS-74. The Radio Society of Okinawa provided technical assistance that allowed students of Lester School's Young Astronaut Program to make contact with Bill McArthur, KC5ACR on board *Atlantis*. The contact occurred on November 20, 1995 during the 115th and 116th orbits of STS-74.

The Radio Society of Okinawa established a ground station at Lester School. The installation of directional antennas on the school roof went a long way in promoting the upcoming event to the school and the community. Prior to the pass, AMSAT member and teacher, Joe Mora, 7J6CBE/KB7HRR provided Young Astronaut Program members with a detailed explanation and demonstration of the Amateur Radio equipment used to make the contact. As a result, Lester Middle School students had the opportunity to ask McArthur a series of questions during the eight-minute pass. Since this contact Mora's students have established the following WWW page to describe their memorable event to the world on Internet: *http://132.15.104.104/Okinawa/School/Schools.html.*■

AMSAT Journal Telemetry

AMSAT Board of Directors Nominations

The time has come again to submit nominations for the AMSAT Board of Directors. AMSAT Member Societies or five individual members may make nominations of fellow AMSAT members to serve a two year term. Three seats on the seven member Board must be filled this year. The Board Members whose terms are expiring are: Keith Baker KB1SF, Tom Clark W3IWI and Andy MacAllister WASZ1B. Be sure that anyone you nominate agrees to serve and understands that meeting attendance is necessary. There are generally two Board Meetings per year - Spring and Fall. Nominations should be marked ***BOD Nomination*** and be sent to: AMSAT, 850 Sligo Ave #600, Silver Spring MD 20910 and ***MUST ARRIVE BY JUNE 15, 1996.***

Phase 3D Shock Testing Successfully Accomplished

A series of Qualification Shock Tests has been successfully completed for the Phase 3D Specific Bearing Structure (SBS). The SBS is the structure that will be used to carry the Phase 3D spacecraft to orbit during launch. These tests were conducted during the week of January 29 to February 2, 1996 by members of the Phase 3D International Satellite Project team in cooperation with personnel at the US Air Force's LMSIL Survivability and Vulnerability Integration Center at Little Mountain, Utah.

The tests exposed the Phase 3D SBS structure to the shock environment that is expected to be encountered on the Ariane 5 vehicle during launch. Following the shock exposure tests the operational performance of the spacecraft's separation system (in full-up, flight configuration) was also successfully demonstrated.

The success of both of these tests has confirmed that the Phase 3D SBS design will withstand both the launch environment as well as to insure the Phase 3D spacecraft will separate cleanly from the SBS after launch.

The International Phase 3D Project Team is indebted to the Little Mountain Facility personnel for their outstanding assistance in completing these important tests.

AMSAT at Dayton

An AMSAT dinner will be held during the Dayton Hamvention at on Friday, May 17th at the Amber Rose Restaurant, 1400 Valley Street, Dayton, OH. A Thruster Firing Hour will be at 6:30 pm with dinner at 7:30 pm. Price for dinner is in the $13 to $15 range. Also AMSAT Local Area Coordinators will meet at this dinner. Please contact Gerd Schrick, WB8IFM (*wb8ifm@amsat.org*) in advance of the dinner as seating is limited to 110 persons.

OSCAR SKN Best Fist Winners

The Grand Prize for Best Fist in AMSAT-NA's 25th Annual Straight Key Night on OSCAR, held January 1, 1996, goes to Russ Hack, NM1K, Enfield, CT. Russ received four separate Best Fist nominations from operators he worked, a new OSCAR SKN record.

Additional Best Fist winners, also nominated by those whom they worked in this year's event, included:

- Jonathan Ward, KA1OLE, Woodstock, VT
- Richard Beerman, N4EL, Houston, TX
- Cliff Buttschardt, W6HDO, Morro Bay, CA
- Enoch Wahlter, SM7BHH, Horby, Sweden
- William Hensel, AA0RQ, Englewood, CO

W6HDO deserves special mention for his having been selected in four of the five years for which we have requested Best Fist nominations. There's consistency for you! Our congratulations to all of this year's Best Fist winners, and thanks to all those who participated in SKN on OSCAR. CU next year!

Frank Bauer, KA3HDO, Receives ARRL Recognition

Last January at an ARRL Board of Directors annual session, Frank Bauer, KA3HDO was awarded the ARRL National Certificate of Merit for his outstanding volunteer service as a member of the SAREX Working Group. Frank is AMSAT Vice President for Manned Space Programs and represents AMSAT on the SAREX Working Group. Congratulations Frank!

AMSAT-UK Colloquium 1996 - Call For Papers

The 11th AMSAT-UK Colloquium will be held at University of Surrey, Guildford, Surrey, U.K., from July 25-28, 1996. Current intentions are to devote the first day to international/IARU matters and to structure other subjects across the following three days.

AMSAT-UK invites authors to submit papers, about Amateur Radio space and associated activities, for this event; we normally prefer authors to present the papers themselves rather than having someone else read them in the authors' absence. Abstracts of papers for presentation should be submitted as soon as possible; the date for full submissions will be announced in a future bulletin. It is likely that the final date will be about one month prior to the event in order that the *Proceedings* document be available to participants. Submissions should be sent to: Chris Jackson, G7UPN, Surrey Satellite Technology, Ltd., University of Surrey, Guildford, England, GU2 5XH (Internet *G7UPN@amsat.org* or direct on UO-22).

Please send all other inquires about the AMSAT-UK Colloquium to the AMSAT-UK, 94 Herongate Road, Wanstead Park, London, England, E12 5EQ

1996 ARRL and TAPR Digital Communications Conference

Mark your calendar and start making plans to attend the year's premier event in Amateur Radio digital communications: *The 1996 ARRL and TAPR Digital Communications Conference* will be held September 20-22, 1996, in Seattle, Washington — just minutes from the SeaTac Airport. Local sponsors include the Puget Sound Amateur Radio TCP/IP Group

and Boeing Employees Amateur Radio Society (BEARS).

The ARRL and TAPR Digital Communications Conference is an international forum for Radio Amateurs and experts in digital communications, networking, and related technologies to meet, publish their work, and present new ideas and techniques for discussion. Presenters and attendees will have the opportunity to exchange ideas and learn about recent hardware and software advances, theories, experimental results, and practical applications. This year marks the first year in which the ARRL Digital Communications Conference and TAPR Annual General Meeting have joined into one conference! For more information on the Conference, registration, and hotel reservations please contact TAPR at the following address.

8987-309 E. Tanque Verde Rd. #337
Tucson, AZ 85749-9399
Phone: (817) 383-0000
Fax: (817) 566-2544
Internet E-Mail: *tapr@tapr.org*
Internet Web: *http://www.tapr.org*

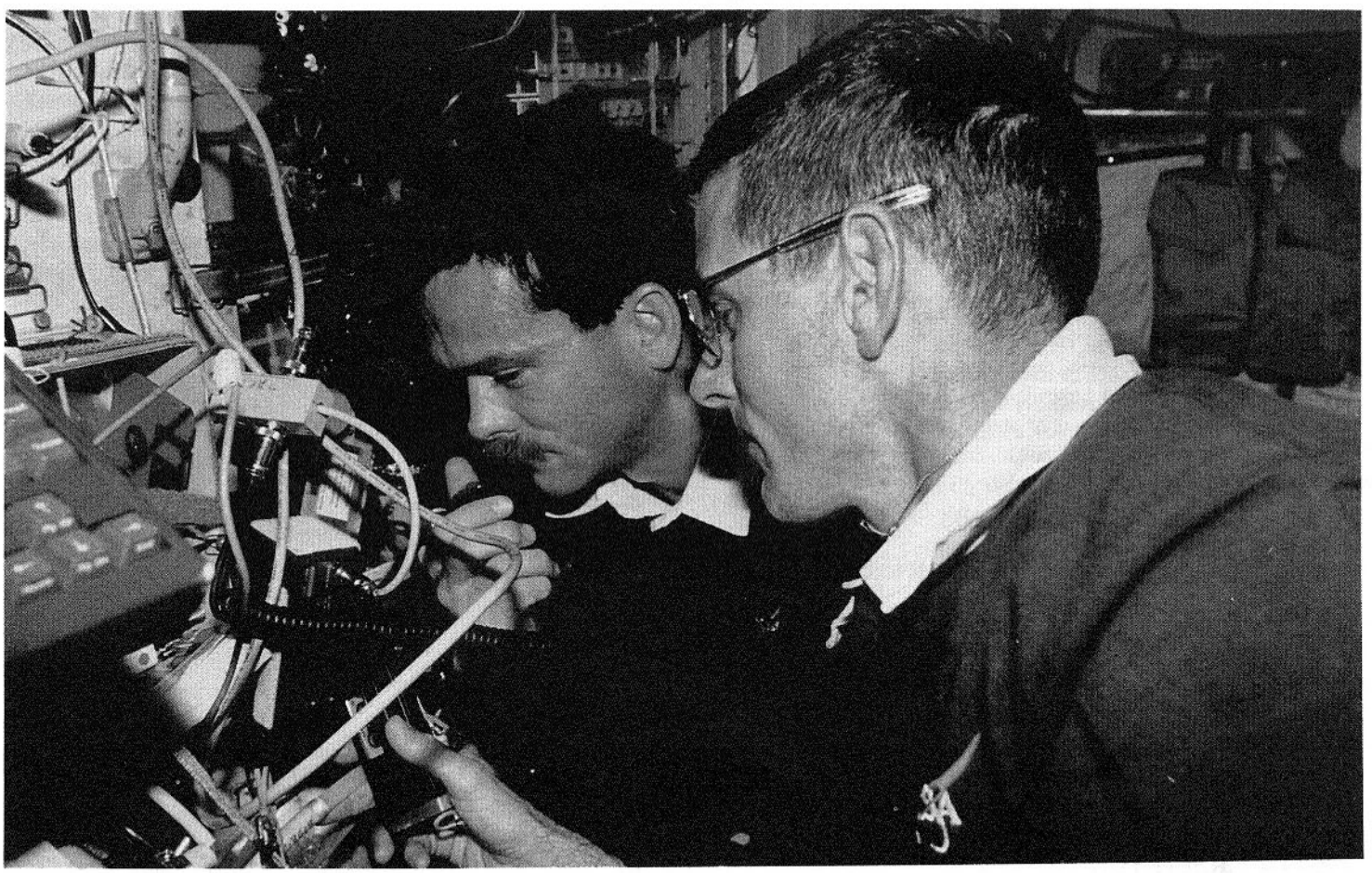
Silent Keys

- John Browning, W6SP passed away on January 3, 1996 at the Torrance Medical Center, California. W6SP was elected Chairman of the Board of AMSAT in 1982 and led the organization during the period when the first Phase 3 satellites were being developed.

- James B. Caton, W1WXZ, of Cape Cod, Massachusetts, died at home on January 18, 1996. Jim was 76 years old and was very active on satellites. His callsign was frequently seen in Pacsat queues and he worked over 170 countries on OSCAR satellites.

- Nick Marshall, W6OLO, of Sebastapol, California became a Silent Key on January 28, 1996. W6OLO was a pioneer in amateur satellites and was one of the founders of Project OSCAR 35 years ago and was serving as its President when he died. AMSAT President Bill Tynan, W3XO said that he had known Nick Marshall for the past 30 years and that he had been an inspiration to the early AMSAT enthusiasts during the early days for the organization's existence. Bill added that, if Nick's dream of an Amateur Radio transponder on the Moon can ever be realized, it should carry the call W6OLO.

- Jim McKim, W0CY, of Salina, Kansas, became a Silent Key February 14, 1996. Jim was born in 1915 and first licensed in 1933. He had been involved in satellites since the launch of Sputnik I in 1957. A Life Member of AMSAT, with a Life Membership Number of 7, as well as a life member of ARRL and QCWA, Jim was known as *Mr. Ham Radio* all over central Kansas. W0CY was an ardent supporter of AMSAT and served as Net Control of the Mid-American Section of the 75-Meter AMSAT Net since its inception in the 1970s.■



STS-74 Astronauts Chris Hatfield, KC5RNJ (left) and William McArthur, KC5ACR check out the R0MIR station aboard Russia's Mir Space Station during their November 12-20, 1995 mission. In the next issue of *The AMSAT Journal*, Lou McFadin, W5DID will chronicle this docking mission that allowed a record eight Radio Amateurs to be aboard the same spacecraft. (NASA)

WELCOME, WELCOME, WELCOME!

Heather Johnson, N7DZU
(n7dzu@AZStarNet.com)

We are certainly looking forward to seeing you in Tucson, Arizona, at the *14th Space Symposium and AMSAT Annual Meeting* to be held November 8-10, 1996! Past symposiums have been great and every year many members have donated untold hours toward creating a memorable meeting. So, why should you specifically desire to come to this year's event!? While it is certainly not because we can outdo the wonderful efforts of those who have preceded us there are some good reasons such as:

- Tucson is a wonderful place, full of Southwest charm and experiences!
- Our weather is notably better than most of you would be experiencing in November...You might even return home with a tan!
- The Symposium is getting special care and attention, and its content will be well worth your airfare.
- Bring your wife and family as we wish to make them especially welcome! I am involved with Amateur Radio because of my husband, Lyle. While I am not a very technical person, I love a technical person, so to be able to do things together, I am involved, and enjoying it! I believe that spouses getting together during the Symposium will be lots of fun.
- We are expecting a successful Phase 3D launch, and the Symposium will be a great place to share the enthusiasm!

Please feel free to contact me via e-mail concerning details of activities, brochures on local highlights.■

Satellite Orbital Elements

by Ray Hoad, WA5QGD

Satellite	AO-10	UO-11	RS-10/11	AO-13	FO-20	AO-27	RS-12/13
Catalog Number	14129	14781	18129	19216	20480	22825	21089
Epoch Time	96065.50375	96065.97042	96066.46933	96067.17107	96066.15658	96066.05446	96066.07665
Element Set	405	880	181	163	875	462	875
Inclination	26.3511	97.7927	82.9225	57.3224	99.0389	98.5928	82.9196
RA of Node	220.9315	61.3254	224.4419	130.8419	110.5437	143.4329	265.8051
Eccentricity	0.5983467	0.0013124	0.0013245	0.7386364	0.0541017	0.0008083	0.0029128
Arg of Perigee	356.318	62.6576	79.4597	33.45	358.0688	168.2294	157.3377
Mean Anomaly	0.5177	297.5971	280.8041	356.6605	1.8324	191.9066	202.9072
Mean Motion	2.05877093	14.6943216	13.72362882	2.09738899	12.83232301	14.27688466	13.74067004
Decay Rate	-0.00000167	0.00000159	0.00000026	-0.00000332	-0.00000001	-0.00000017	0.00000042
Epoch Rev	9570	64249	43608	5918	28467	12727	25487
Satellite	KO-25	RS-15	UO-14	AO-16	DO-17	WO-18	LO-19
Catalog Number	22828	23439	20437	20439	20440	20441	20442
Epoch Time	96066.13409	96065.77021	96066.11809	96066.07983	96066.11229	96066.16992	96066.17351
Element Set	445	117	176	966	970	980	968
Inclination	98.5879	64.8144	98.5516	98.5647	98.5658	98.5651	98.5685
RA of Node	143.7074	190.3252	151.0495	153.0643	153.6787	153.6813	154.143
Eccentricity	0.0009894	0.0163428	0.0010893	0.0011393	0.0011545	0.0012223	0.0012265
Arg of Perigee	153.1637	217.2371	140.0052	142.4553	140.9403	142.4117	140.3567
Mean Anomaly	207.0058	141.7127	220.1935	217.7417	219.2598	217.7923	219.8507
Mean Motion	14.28132079	11.27523972	14.29913272	14.29967799	14.30109488	14.30079847	14.30186927
Decay Rate	0.00000006	-0.00000039	-0.00000013	-0.00000032	0.00000013	0.00000015	0.00000023
Epoch Rev	9540	4912	31932	31933	31936	31937	31939
Satellite	UO-22	KO-23	IO-26	HUBBLE	MIR	NOAA-9	NOAA-10
Catalog Number	21575	22077	22826	20580	16609	15427	16969
Epoch Time	96066.13917	96065.99917	96066.05859	96067.57663	96066.06615	96067.01422	96066.96506
Element Set	677	574	461	780	438	611	529
Inclination	98.3655	66.0768	98.5929	28.4688	51.646	98.9586	98.5179
RA of Node	135.5385	45.5027	143.5821	151.681	280.6843	131.8248	66.9798
Eccentricity	0.000656	0.0008689	0.0008523	0.000596	0.0005653	0.0014105	0.0012542
Arg of Perigee	215.2892	325.621	169.4055	188.1128	66.1462	242.6026	296.506
Mean Anomaly	144.7862	34.4225	190.7292	171.9363	293.9955	117.371	63.4835
Mean Motion	14.37013792	12.86295915	14.27796303	14.91022618	15.57696693	14.13765575	14.24975527
Decay Rate	-0.00000014	-0.00000037	-0.00000016	0.00000362	0.00002714	0.00000059	0.00000024
Epoch Rev	24326	16753	12728	12340	57393	57919	49204

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- ☐ CW Narrow Filter (optional)
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IC-820H 2 M/440 MHZ Dual Band All Mode Transceiver

The IC-820H isn't your typical base station transceiver. This all mode dual bander has compact and lightweight dimensions offering operating versatility other base stations just can't match. Mobile and field operations are ideal with this rig. But don't let its size fool you. This is a high performance transceiver with state-of-the-art construction, circuit design and cutting edge features.

ICOM's **Newly Designed I-loop DDS** (digital direct synthesizer) is employed in the PLL circuit of the IC-820H. Previous PLL circuits for 10 Hz resolution transceivers contained 2-loop circuits. The new I-loop has a single loop and **Generates a Signal with Superior 1 Hz Resolution**. ICOM's DDS PLL also contains a normal PLL as the main-loop and a DDS as the sub-loop.

Satellite operation with the IC-820H's **Built-In Satellite Functions** has never been this easy. These include **Normal and Reverse Tracking** for different modes of satellite communications; **Independent Uplink/Downlink Control** for Doppler shift compensation; **Separate Satellite VFO** and **10 Dedicated Satellite Memories** provide quick switching from normal to satellite operation as well as easy recall of satellite and downlink frequencies.

With **Independent Controls and Indications for Both Bands**, this dual bander is as easy to operate as most single band transceivers – and exchanging the main and sub bands is just a switch away. **Separate S-Meters** simultaneously indicate each band's respective signal strengths.

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The IC-820H's **Compact Size** enables easy installation in a shack as well as a vehicle. Overall dimensions may be small, but important points such as LCD size and space between switches are more than adequate.

An important consideration in all mode transceivers is the interference reduction circuit. The IC-820H's **IF Shift Circuit** electronically shifts the center frequency of the receiver passband to evade interfering signals.

The IC-820H's **DATA Terminal** (in ACC socket) is connected to its modulator circuit directly. This **Data Jack supports Packet Operation** at up to **9600 bps**. A newly designed **Modulation Limiter Circuit** prevents you from exceeding the maximum deviation – even with large amounts of data.

For more information about the IC-820H, visit your local ICOM dealer, contact ICOM Technical Support in the HamNet forum on CompuServe®@ 75540,525 (Internet: 75540.525 @ compuserve.com) or **call ICOM's brochure hotline: (206) 450-6088.**

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